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GENERAL SESSIONS

President's Report

PERC A. REEVE[1]

Fellow Society members and friends, it is with a feeling of pride as well as humility that I speak to you this morning on behalf of the officers of our Society. We deeply appreciate the support and cooperation that you have given us these past two years and hope that we have fulfilled the trust and confidence that you placed in us.

We feel that the Society has grown in size and stature during the past two years, and certainly the number in attendance here this morning would at least bear out that we have grown in size. I understand that we have 450 registered for our meeting so far and they are still coming.

We are very happy with the growth and increased interest of the factory personnel in our Society. I think it speaks well for, and points the way towards, an even closer working relationship between the field and the factory. I feel that an excellent program has been outlined for us and that we will leave Salt Lake City Friday convinced that we have had the most instructional and progressive meeting of the Society, to date.

Again, referring back to the increased growth and stature of the Society, let me read to you a statement that appeared recently in the "International Sugar-Journal, September, 1951, issue, Vol. LIII, No. 633":

> Quote . . . We draw attention to the remarkably high quality of research which is now going on in the American beet sugar industry, as reflected in the pages of the Proceedings of the last General Meeting of its technologists' Society. Excellent progress is reported by the breeders in obtaining varieties resistant to pests and diseases, giving higher and yet higher yields of sugar per acre. Monogerm sugar beet varieties, which so far have not been developed in Europe, are now being expectantly studied. Searches for improved methods of harvesting are in progress. Better practices in the use and application of fertilizers are revealed, and some useful information on irrigation is to be found in these pages. New weed killers are being developed. In short, this volume contains literature which should be studied by the cane agriculturist and the cane technologist, as well as by their beet colleagues . . . Unquote.

The industry is spending more of its dollars on research today than it has at any other period in its history. The wisdom of this policy is evident in the progress that has been made and the tremendous developments which are yet to come as a result of this research program.

The Great Western Sugar Company has just completed at Longmont, Colorado, what we might call the latest in factory design to house its sugar beet technologists. The formal ceremonies attending the opening of this spacious building, with its laboratories, greenhouses, etc., were just held Saturday evening. I regret that I was unable to attend these ceremonies and share in the pride of accomplishment and hope for the future with our fellow Great Western sugar beet technologists.

This new experiment station is evidence of the value and importance that the Great Western Sugar Company places on sugar beet research as well as being a tribute to the accomplishments of their technologists. All companies are moving in this same direction.

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[1] President, American Society of Sugar Beet Technologists, 1950-51, Agricultural Supervisor, Farmers and Manufacturers Beet Sugar Association.

Our sugar beet industry today is a product of the accomplishments of sugar beet research. The beet sugar industry could not have survived on this North American continent had it not been for the efforts of our own American sugar beet technologists. Several of the technologists who began this great drama of man against the elements are in this room today; several others are not; certainly we pay tribute to all of them.

I should like to pose the following thought: as sugar beet technologists, are we not the number one men of the North American Sugar Beet Family? The future prosperity of the industry is in our hands just as certainly as the past prosperity of the industry is the product of the developments of the sugar beet technologists. In making this statement, I am aware that management, legislation, sales and all other lines of the industry must be effective.

I feel honored this morning occupying the same speaking rostrum with such distinguished gentlemen as President Clark and President Madsen. I deeply respect these gentlemen and the institutions which they represent, both of which have had a marked influence upon my life.

Inasmuch as my opening remarks have dwelled somewhat on the past and future, I thought it might be well to make that the theme of my talk. The setting of this meeting lends itself to such a theme, because it was some 100 years ago in this very Salt Lake valley that the sugar beet industry of the North American continent truly began its great drama. (As a sideline I might mention that it was just 34 years ago, just a few miles north of here at Brigham City, that I began my earthly existence. Further, that I have been most tenaciously attached to the sugar beet crop and industry since that day some 34 years ago, and I sincerely hope that the same attachment will exist for many more years to come.)

But getting back to this reminiscing theme, I would like to ask each of you the question:

What is the first recollection or contact you had with the sugar beet crop or sugar beet industry? I would like to spend a few minutes relating some of my early memories. I invite you to reminisce about yours as I talk.

I was about 6 years old when my father took me by the hand one warm day and led me down to our sugar beet field that had just been blocked and thinned—that is, all excepting the two outside rows on each side of the field. These were so weedy that the labor had refused to work them. I don't recall the deal or how Dad convinced me that I was to do the blocking and thinning job, but somehow he did. Neither do I recall how long it took me or any of the details, but I do remember that I got paid for it, and I took my earnings and bought some red paint and repainted my wagon.

I must have done a pretty good job of thinning because, starting the next year, my two older sisters and I began to take over the thinning of our sugar beets. The younger members of the family joined the crew as they became old enough.

I recall how Dad and the fieldman impressed upon us the importance of doing a good job of thinning, of leaving a good stand of beets, of getting rid of the weeds, etc. I also recall that it got hot and that we got tired,

especially our backs. I remember that my oldest sister crawled most of the time, so she had mother make pads for her knees. I also recall how we watched and silently prayed for storm clouds to come drifting across Great Salt Lake and when the first drops of rain hit our big straw hats, it was our signal to run for the house; usually to have the storm blow over and for us to trudge wearily back to our thinning job. It was then that we usually talked and dreamed of the day when machines would be developed and kids would no longer have to undergo the torture that we were put to.

We used to grow some pretty big weeds in our beets fields at home—especially water grass and pig weeds. As I recall, some years they got so big and thick in our beet fields that it was like a jungle. In order to pull them, we would have to gang up—2 or 3 of us getting on one plant—and then sometimes taking only a portion of the grass plant at a time. We would especially like to come to the cross ditches used for irrigation, for usually these ditches had sand in the bottom and we would quite often stop and build sand castles while we rested. Even though building sand castles, we would dream sugar beet castles and it is surprising how much imagination one can generate under such circumstances. In our sand castles, we certainly solved many of the problems of growing sugar beets.

On our farm, as a youth, I saw the value of using green manure crops, of feeding livestock and of using commercial fertilizers to secure maximum sugar beet yields.

Since then, I've come to more fully appreciate the tremendous service that the sugar beet industry has done in helping to establish and maintain sound agricultural practices in the areas in which it operates. I've also come to realize that the establishment of the sugar beet industry in a given area means that the income of that area will be materially increased; that the standard of living will go up and that, as I mentioned, the level of farming will be vastly improved.

Why is this so? What is the magic behind the sugar beet crop that makes these changes take place?

To me the two prime reasons are:

1. **Sugar beets are a demanding crop. To grow them profitably, a farmer must follow sound farming principles.**
2. **Sugar beets are a high value cash crop which pays the farmers handsomely for following sound farming practices.**

The beet sugar industry, in recognizing these facts, has employed specialists or seen that there are specialists who work on all phases of sugar beet agriculture to help the growers in adopting and maintaining sound agricultural practices on their farms. The sugar beet industry is unique in the services that it offers to its growers. As a result of these services, sugar beet farmers have become outstanding farmers and citizens.

I've never forgotten the year the U. S. No. 1 sugar beet seed was first made available to growers. (To those of you who are not acquainted with U. S. No. 1, it was the first curly top resistant variety released for general grower use.)

I remember Dad mentioning that the sugar company was making this curly top resistant variety available and that their tests showed that under heavy curly top infestations it materially out-yielded the standard commercial variety.

We had never had a serious curly top outbreak on our farm, so Dad finally decided to let somebody else experiment with this new seed. So we planted the old standard variety. We got a severe "curly top" outbreak on our farm that year. We didn't harvest a beet. Our neighbors who had gone along with the new seed U. S. No. 1 had fairly good crops. That is the only poor beet crop I ever remember having on our farm. I was only in my early teens, but I remember the effect the loss of the beet crop had on the family purse.

Personally, I take a great deal of pride and satisfaction in letting the public know what we have done as an industry. I also like to challenge other agricultural industries to get out and do the same, rather than relying solely on government and state agencies for research and grower education. I make this statement fully appreciating the tremendous help that the industry has received from government and state agencies as well as private individuals and industries. We will have to be even more independent in the future.

When I think of the progress that has been made in my short life span and view conservatively what progress we can expect in the next few years, I can see nothing but a bright future for the beet sugar industry.

As sugar beet technologists, I feel that it is well for us to review our accomplishments, both individually and collectively; that we should stop at those CROSS DITCHES occasionally and BUILD DREAM CASTLES of the future; that we should work together—GANGING UP ON THE WEEDS of the industry—removing them section by section if necessary.

As sugar beet technologists let's maintain our standing as the NUMBER ONE MEN of this great North American Sugar Beet Family.

The Role of Sugar Beet Technology Under the Sugar Act[1]

ROBERT H. SHIELDS[2]

I appreciate the opportunity to take part in this seventh general meeting of the Society of Sugar Beet Technologists.

It is significant that your president has asked me here to talk about the Sugar Act. This suggestion evidences your appreciation of the direct, although not usually obvious, relationship between the Sugar Act and the very important fundamental work which you are doing for the domestic beet sugar industry on the technological front. It is also most appropriate that we should talk awhile here today about the Sugar Act because in the final analysis the Act not only underwrites the splendid opportunities which you now have to continue your outstanding technological work both in field and factory but also presents you with a clear challenge to press forward with this work with even greater speed and effectiveness.

The Sugar Act underwrites your present technological opportunities by undertaking to protect the welfare of the domestic sugar producing industry. The Act seeks to achieve this objective by giving the Secretary of Agriculture the power to maintain a fair and equitable level of sugar prices in the United States. The Secretary is enabled to do this by means of his authority to exercise substantial control over sugar supplies available to this market. Under the law, this regulation is accomplished through the Secretary's management of sugar marketing quotas.

The Sugar Act does not specify the precise level of sugar prices which the Secretary is to maintain. The Act does, however, describe its general sugar price objective in terms of prices fair both to producers and consumers of sugar, enumerating several factors which the Secretary shall consider in applying this broad standard. These factors include the amount of sugar distributed in the previous year, needed adjustments in sugar stocks, changes in population and demand conditions, and the relation of sugar prices to the general level of the cost of living during the first ten months of 1947.

This period in 1947 will, I am sure, be recalled by all of you as the time when sugar was still under price ceiling control and all other commodities had been decontrolled. In requiring consideration to be given to the relation which prevailed during this 1947 period of sugar prices to the general cost of living, the Congress made it clear that it considered sugar prices in that period to have been eminently fair to consumers. The inclusion of this formula among the several factors which the Secretary is required to consider in implementing the general fair-price standard in the Act is, in effect, a legislative finding that sugar prices at the level which would maintain this relationship could not at any time be unfair to consumers.

When the direction to the Secretary contained in the Act with respect to the determination of sugar consumption requirements is considered in relation to the provisions of the law establishing fixed quotas for domestic

[1] Presented by H. B. Boyd in absence of Robert H. Shields.
[2] President and General Counsel, United States Beet Sugar Association.

sugar producing areas, the level of sugar prices which are fair both to consumers and producers at any time becomes quite clear. The Act establishes fixed marketing quotas for each of the domestic sugar producing areas in recognition of the protection afforded consumers by maintenance of a strong and healthy domestic sugar industry. Accordingly, since it follows that the Act contemplates that sugar prices will be maintained at levels which will enable the domestic sugar producing areas to reach the goals fixed for them in the Act, prices adequate to achieve this purpose may properly be regarded as the minimum level necessary to maintain and protect the domestic sugar-producing industry as the Act contemplates.

Since the annual goal which the Sugar Act sets up for the domestic beet sugar area is 1,800,000 tons, raw value, certainly the Act intends that prices for sugar will at least be such as to maintain this industry at that level of production.

This view is most recently stated by the Department of Agriculture in its 1952 instructions to officials in the field with respect to the 1952 national goals program. The fact that this Sugar Act goal of 1,800,000 tons, and the price provisions to support it, were recently extended through the year 1956 should give you renewed assurance that the basic work in which you are now engaged will continue to have industry-wide support in the years immediately ahead. On the other hand, in the light of where the industry now stands, this extension of the Sugar Act through 1956 also presents a clear challenge to you to press forward with even greater speed and effectiveness on the technological front.

This challenge stems not only from the fact that the Sugar Act, as it is now on the books, expires at the end of 1956, but also from the fact that the Act is not a self-executing guarantee that the domestic beet sugar industry will be able continuously to measure up to its 1,800,000-ton goal between now and 1957. Moreover, looking beyond the term of the present law, there is no assurance that consumers of sugar will continue to look to the domestic beet sugar industry for an increasing portion of their sugar requirements unless in the meantime the industry continues to prove itself an efficient and reliable source of sugar supply.

The sharpness of this challenge lies in the fact that, in the 4 years just past since the enactment of the 1948 Act, the industry has attained its 1,800,000-ton goal in only one year. That was in 1950 when production reached 2,012,000 tons; whereas, with a low of 1,370,000 tons in 1948, the average production for the 4-year period 1948-51 has been only 1,635,000 tons.

It is probable that, if sugar prices in the last few years had been maintained at a somewhat higher level, particularly at sugar beet planting time, the industry's average annual production since 1948 would have been nearer its present 1,800,000-ton goal. Looking ahead, however, the realistic steps which the Secretary of Agriculture has taken with respect to 1952 are grounds for hoping that sugar prices during the remainder of the term of the Act will be more in line with the needs of domestic sugar producers. Nevertheless, it must be recognized that the sugar quota mechanism is not a precision instrument and also that its management is subject to the errors

of human judgment. We must also all recognize that the distorted demand of these explosive times for some of the crops which compete with sugar beets has intensified the difficulties inherent in successfully managing the sugar quota system.

In view of these difficulties, and the Secretary's equal responsibility for protecting the interests of consumers, your persistent efforts to develop new techniques to reduce the cost of producing and processing sugar beets are more necessary now than ever before.

We must never lose sight of the fact that the farmer is not so much concerned with the unit prices which he gets for his products as he is with the net returns which they provide. Every man-hour of direct labor cost which can be eliminated is just as effective in improving the competitive position of sugar beets as would be a corresponding increase in sugar prices. The same is true with respect to any improvements which can be accomplished in the direction of higher and more dependable yields. Moreover, we must also remember that technological improvements are continually being made in connection with the production of crops which compete with sugar beets. To keep pace with these developments with respect to competing crops is still another reason why we need to wage a continuous and unrelenting battle to increase the efficiency, and lower the costs, of beet sugar production.

In addition to the competition between sugar beets and alternative crops, we must recognize, too, that unless the beet sugar industry keeps abreast of the technological advances made in other sugar-producing areas supplying the United States market, both foreign and domestic, the enviable position which our industry has attained as a result of your effective work in the past will be jeopardized.

This reference to the effective work of the past, of course, embraces not only the work done by technologists within the beet sugar industry but also the very substantial contributions made by state and federal scientists. While continued public support for sugar beet technological work is to be expected, since the essentiality of the beet sugar industry to our national economy was again demonstrated dramatically during World War II, nevertheless, a realistic appraisal of the signs of the times would seem to indicate that the beet sugar industry itself will undoubtedly have to carry a larger and larger share of the cost of research in the future.

This trend has already prevailed for some time. For example, the amount of money provided for sugar beet research in the division of sugar plant investigations in the U. S. Department of Agriculture for the fiscal year 1952 is less than the $265,000 spent during the fiscal year 1933. The effect of this decrease in government appropriations for sugar beet research work is accentuated by the fact that one dollar today buys only about half as much research as it bought in 1933.

Undoubtedly, members of Congress believe, as we do, that it would be in the public interest for the Government to carry on at least as much sugar beet research today as it did 20 years ago. We must recognize, however, that with expenditures of the federal Government in peace-time

amounting to upwards of 85 billion dollars a year—ninety percent of which is for war, past, present or future—it is not realistic to expect large increases in federal funds for sugar beet research when emphasis is being placed on reducing federal non-defense expenditures as much as possible. These circumstances increase the need for making most effective use of funds available for sugar beet technological work by maximum possible cooperation among all companies within the industry and between the industry and the government.

In conclusion, let me say again that I appreciate this opportunity of talking with you about the Sugar Act in relation to your work. I know of no more important role being performed by anyone in the industry than that which you perform. And this role, it seems to me, is made all the more important by the existence of the Sugar Act.

In review, the things which you have accomplished in the past are almost unbelievable. For example, as things have turned out, it could have been forecast with accuracy 50 years ago that by today you would have doubled the amount of sugar produced from an acre of sugar beets. But for this achievement of yours would the beet sugar industry in the United States have increased 40 fold in the last 50 years? With improved scientific methods and techniques available now, am I justified in predicting that within the next 25 years you will again double the average production of beet sugar per acre?

Research Work in Sugar Beet Breeding

H. W. DAHLBERG[1]

I believe this is one of the first occasions on which a talk on research in sugar beet breeding has been given at a general session of the Society. Recognizing that many of my listeners have been trained in other phases of the industry rather than in plant breeding, I shall make a determined effort to make my talk as understandable as possible to the average layman and business man.

In this country, as well as in all European countries, the major objective has been to develop beets which, consistent with high quality for slicing purposes, will give the maximum production of sugar per acre. This major objective must never be forgotten, and all other objectives are subsidiary to it. The industry can neither afford to use varieties which may produce high tonnage with only 14 percent sugar content, nor varieties which may reach 18 percent sugar content at the sacrifice of several tons of beets per acre.

Prior to 1920, most of the breeding work on sugar beets had been done in Europe, and while many excellent varieties had been developed, they had their shortcomings for American conditions. Thus, for example, they had no resistance to the dread curly top disease, which took a heavy toll west of the Rockies, nor to the leaf spot disease which often did serious damage east of the Rockies. The varieties were not well adapted for the long seasons and widely different climates in California, for winter growing in the Imperial valley, nor for the short seasons in Colorado, Wyoming and Montana. It has therefore been necessary for American breeders to develop entirely new and improved sugar beet varieties to meet all the varied climatic conditions in the United States and Canada.

I am sure that most of you are already familiar with the history of the development of U. S. 22 and other curly top resistant varieties by the sugar division of the Bureau of Plant Industry. It provides an important chapter in the record of American plant breeding, and I wish to pay my tribute to the men who were the leaders in this fine piece of work.

A research study now in progress, and one in which we are all engaged, is that initiated by the Savitskys for the production of single germ seed. This will be a tremendous step forward, and beet growers should begin to see its possibilities in three or four years more. It will, of course, take time to add this single germ character to our present varieties and still retain all the other important characters. Dr. Owen and his staff are doing very outstanding work along these lines right here in Salt Lake and elsewhere.

Chemical Breeding

For many years I have been particularly interested in the chemical phases of sugar beet breeding. I feel rather strongly that we will be unable to develop varieties of maximum sugar content and purity until we know more about the chemical processes that are involved in the production of sugar in the leaves by photosynthesis. In spite of volumes of research work

[1] Director of Research, Great Western Sugar Company.

done by chemists and plant physiologists, our knowledge of the actual process of sugar formation leaves much to be desired. As chemists, we know that photosynthesis is a very complex process, possibly involving as many as fifteen individual chemical reactions.

"Photosynthesis is by far the most important biochemical process on earth because it alone produces organic matter from stable inorganic materials and thus prevents life from becoming extinct. It is also the most puzzling of all biochemical reactions." (Rabinowitch)

In recent years rapid progress in understanding these reactions has been made by the use of radioactive carbon which is used as a tracer element. By the use of radioactive tracers, it has been learned that a number of organic acids are formed before sucrose is formed, and one of the important acids is glycerophosphoric acid. It is evident from the knowledge that has already been acquired that many chemical reactions and many enzymes are involved in the production of sugar. Anything which interferes with or slows up these reactions results in a lower concentration of sugar in the beet. An example of such an interfering element is an excess of nitrate which invariably results in lower sugar content.

A mechanical analogy to the production of sugar in beet leaves would be the transmission of power through a train of gears. We all know that, if one gear wheel in a series breaks down, all power transmission stops. In the same way, if one chemical component, such as an enzyme or a catalyst, fails in a chain of fifteen chemical reactions, the production of sugar will stop for a certain length of time.

In the past, it has been extremely difficult to develop sugar beet varieties of high sugar content without losing ability to produce good tonnage in the process. In other words, if one is willing to sacrifice tonnage, it is relatively easy to breed a variety of maximum sugar content.

Table 1 shows the contrast between one of our varieties with emphasis on maximum production per acre, and a European variety with emphasis only on maximum sugar content.

Table 1.—Average Results of Variety Tests at Three Locations, 1951.

Variety	Tons Per Acre	% of Mean[1]	Polarization	% of Mean[1]	Total Sugar per Acre	
					Pounds	% of Mean
B 530	23.71	106.2	17.25	101.8	8201	108.2
European	18.18	81.6	17.49	103.3	6374	84.3

[1] Mean of 20 Varieties.

In recent years, we have developed a new tool which makes the breeding for sugar content somewhat more certain. We have learned that high sugar content and low sodium content normally go together. In other words, a variety which can grow normally and efficiently with a minimum sodium content has a high sugar content. The sugar beet seems to have a very small physiological need for sodium salts, such as sodium chloride and sulphate. As the statisticians express it, there seems to be a high negative correlation between sugar and sodium content.

I believe you will be interested in Table 2, which shows this relationship in various types of varieties.

Table 2.—Typical Analyses of Various Types of Beets.

	Year	% Sugar	% Sodium	Ratio Sugar to Sodium
Stock Beets	1950	4.8	.220	22 to 1
Swiss Chard	1951	6.3	.287	22 to 1
A-1104	1951	15.28	.036	424 to 1
5 European Varieties	1948	15.94	.066	241 to 1
G. W. 304	1948	16.52	.041	403 to 1
B 476	1950	18.68	.018	1,037 to 1
G. W. 359	1951	18.50	.021	881 to 1
B 476	1951	18.90	.014	1,350 to 1

It may be quite a few years before we will know just why high sugar content and low sodium content normally go hand in hand, but in the meantime we can still use the sodium determination as a very useful tool in breeding beets of high quality. I suspect that a rather high sodium content interferes with one or more of the enzyme reactions which are necessary for the formation of sugar in the leaves. We also know that a high nitrate content in beets interferes with the production of sucrose, and causes the beet to have a high ash content and therefore low purity. Sugar production in the beet is also inhibited by phosphorus deficiency.

In our selection work this winter, we tested more than 6,000 beets individually for sodium content by means of the flame photometer. We have already demonstrated that we can reduce the sodium content approximately one-half by one generation of careful selection.

Another phase of our chemical breeding work is the study of raffinose and other carbohydrates which we have carried on for several years. This work is described in more detail in the program of the Genetics section. Mr. R. J. Brown of our research laboratory has succeeded in developing a method whereby we can determine raffinose in individual beets, and we are working on the problem of developing a low raffinose variety. We find variations as high as 400 percent in the raffinose content of individual beets, so we feel it should be entirely possible to achieve a reduction of 25 percent to 40 percent of the normal raffinose content of our beets.

Those of you who have worked with the Steffen process know how much trouble can be caused throughout the sugar end by the presence of too much raffinose in the white and raw massecuites. We feel that this may be a very worthwhile phase of breeding work.

Raffinose seems to be accompanied by two other sister carbohydrates which have not yet been fully identified, and which we call carbohydrate "X." We believe carbohydrate "X" is just as objectionable as raffinose, so it is important that we learn all we can about it, and whether we can develop varieties which carry as little as possible of these two compounds. Our present varieties normally contain 0.33 percent raffinose on sucrose, and it is indicated that we have a higher concentration of carbohydrate "X" than we do of raffinose.

You may be interested to know that while there is normally only one pound of raffinose in a ton of beets, this objectionable sugar builds up in our Steffen process to the extent that in our company we circulate and recirculate 1,000 tons or more of raffinose through our Steffen houses and Johnstown in an average campaign. It must also be recognized that the presence of appreciable amounts of carbohydrate "X" in our juices and sirups makes many previous determinations of raffinose of questionable accuracy.

One important phase of our breeding work is that concerned with the reduction of sugar losses in storage of beets. We are attacking this problem from two angles: (1) Careful selection of beets from our best varieties which have a low rate of respiration; (2) selection of those individuals which are slow to show decay when exposed to rotting organisms such as Phoma. This work is relatively new, so we cannot yet say how rapidly we will make progress. However, we believe this phase of breeding offers considerable promise.

Development of disease resistance is, of course, one of the major objectives of any breeding program. Our company, as well as the American Crystal Sugar Company and the Holly Sugar Corporation, has developed leaf spot-resistant varieties particularly suited to our own areas. The sugar division of the Bureau of Plant Industry has developed leaf spot-resistant varieties which are used largely in Michigan, Ohio and Ontario, and curly top-resistant varieties which are used in many areas west of the Rockies. This division and some of the California companies are also making progress on varieties which are resistant to bolting and have some resistance to downy mildew.

We are also having success in breeding beets which show considerable resistance to fusarium yellows, a rather dangerous disease. We are working on the problem of developing resistance to rhizoctonia, and while this is a very complex problem, we believe we are making progress. The danger from these two diseases can be reduced by rotation of crops and improved farming, but we also think it desirable to have beet varieties which show some resistance.

We are devoting considerable effort to cold resistance studies. In this work we have three objectives: (1) To increase the length of the growing season; (2) to avoid freezeouts in the spring which often result in lost acreage and replanting; (3) to secure the higher sugar content which tends to go along with cold resistance. In this work we grow very large numbers of seedlings in greenhouse flats. The first step is to expose them to a conditioning or hardening temperature just above freezing. The second step is to expose them to temperatures as low as 12 degrees F. Slides which will be shown will give you a better idea of these studies. Up to this time, we have exposed some 25,000 seedlings to low temperatures.

During the next fifteen years, greater emphasis will doubtless be placed on securing many inbred lines with all the desired characters, which can be used with the male sterility character to produce hybrid varieties which will be more productive than those we have today. Such a program will involve a great deal of work, and close cooperation between the breed-

ing divisions of the industry and of the United States Department of Agriculture. I am glad to note that this cooperation is already off to a very promising start. The work with inbred lines will involve many problems of working with large populations, of saving weak lines, of poor seed production, control of the male sterility factor, etc.

Another phase of breeding work which may demand attention in the near future is the development of polyploid varieties. A great deal of work on this subject is being done in Germany, Denmark and Sweden, and the preliminary results reported indicate that such varieties may be more productive in either sugar content or tonnage. Such varieties will doubtless be tested in this country during the next few years.

I think we are fortunate in this Society in being a young organization, even though some of us are no longer young in years. In closing my review, I wish to make this plea to the younger scientists who will carry on the research work in beet breeding for the next twenty years—**above everything else, be open minded.** Do not hesitate to study any tool or any theory which may lead you forward.

An outstanding cytologist, Hoskins of Wisconsin, in commenting on the long time lag in the acceptance of the chromosome theory of heredity, makes this statement, "There are commonly said to be three stages in the acceptance of an idea: (1) We don't believe it; (2) it's of little or no significance; (3) we knew it long ago. There seem to be similar stages between the first discovery and final acceptance of many scientific data."

As research men, let us not fall into any such habits of thought. Let us learn to understand and speak the language of all the scientists working in our general field, whether it be genetics, cytology, chemistry or plant physiology.

Factors Affecting Healthy Roots

CECIL H. WADLEIGH[1]

Except for the ravages of insects and plant diseases, and the density of plant population, practically the only environmental factors we can control in the production of a crop of beets are those prevailing in the soil and thereby exerting their influence on the plant via the roots. The role of the root environment has been discussed so many times that the present discourse may seem trite. Yet the key importance of the environment about beet roots justifies reiteration of established principles and evaluation in terms of current physiological concepts. Since pathogens, nematodes, and insects may have major effects on roots of beets, this discussion will be confined to roots free of parasitism.

Primarily we look upon the soil as a reservoir for nutrients and water as well as a medium in which roots may grow successfully. Obviously, the effective utilization by the plant of this reservoir we call the soil depends in large measure on the degree of penetration and proliferation brought about by root growth. To be sure, the physical nature of soil will condition the extent to which the nutrient and moisture reservoir will be used by the roots, but comment on this point may well be deferred until certain general aspects of beet roots are first considered.

Andrews (1) found beet roots penetrating to a depth of more than 7 feet in an alluvial soil at Scottsbluff, Nebr. He reported that the roots completely filled the soil down to this depth, and then there was an especially high degree of proliferation in the surface foot of soil. Jean and Weaver (2) reported beet roots penetrating to a depth of 6 feet on irrigated soil at Greeley, Colo., and also emphasized a high degree of proliferation in the surface foot. These studies indicate the extensiveness of the root system and the mass of soil that is potentially available to a beet plant as a reservoir for water and nutrients. That is, the roots of a vigorous beet plant may occupy 8-20 cubic feet of soil.

It is essential that we also evaluate roots in terms of surface exposed to the soil mass permeated, since the primary activities associated with roots are surface phenomena taking place at the root-soil interface. The extent of the root surface determines the total capacity for the plant to take in water and nutrients at a given rate of entry per unit area of surface. It also gives us a measure of the extent to which the surfaces of the soil particles are actually contacted by roots.

No information is available on the total area of root surface of a maturing beet plant growing in soil; but it is of interest to consider the data obtained by Dittmer (3) from his measurements on the root system of a single winter rye plant grown in the greenhouse during the winter for four months in a container 12 inches square and 12 inches deep, filled with a dark loam. The roots were very carefully liberated from the soil at the end of the experiment, by spraying with water several hours. From detailed measurements of extensive samplings it was determined that this plant had approximately 13,800,000 roots, with a length of more than 385

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[2] Numbers in Parentheses refer to Literature Cited.

miles and a surface area of about 2,550 square feet. The root hairs of this plant numbered approximately 14,000,000,000 with a total length of more than 6,600 miles and a surface area of about 4,300 square feet. The data for the length and surface of the roots of this single rye plant appear to be astronomical, but Pavlychenko (4) has made similar observations.

It is recognized that the root systems of graminaceous plants tend to be more highly proliferated than those of most dicotyledonous crop plants. Yet, if one rye plant growing in one cubic foot of soil could have nearly 7,000 square feet of root surface, it seems conservative to estimate that the beets excavated by Andrews (1) and found penetrating to a depth of 7 feet would have at least 10,000 square feet of root surface per plant.

As a further basis for our proposed calculations, it is conservative to estimate that our typical beet plant grew at the rate of 50 grams fresh weight per day during the period of most vigorous vegetative growth. Let us assume that the plant contained an average of 0.5 percent nitrogen on the fresh weight basis. Then each increment of 50 grams of fresh weight implies that 250 milligrams of nitrogen would need to be taken in from the soil each day. On the basis of Avogardo's number (6.06×10^{23}), 11×10^{21} nitrate ions would need to enter the root systems each day to provide the 250 milligrams of nitrogen. This means that 1×10^{15} nitrate ions would enter each sq. cm. per day; or 100 million nitrate ions would enter each square millimeter of surface each second.

Thus, if our estimation of the total root surface of a beet plant seems fantastically high, it still means that ions have to enter a given unit area of roots at a seemingly high rate. Furthermore, we know that meristematic parts of the root system are far more conducive to the entry of ions than the older suberized portions. Also, there are millions and millions of other ions entering each square millimeter of absorbing surface per second along with the nitrate ions.

This suggests that actually billions of ions are diffusing across each square millimeter of actively absorbing root surface per second along with many more billions of water molecules. Visual inspection of absorbing roots gives an impression of complete quiescence, but if one could view conditions at the root surface by a sufficiently powerful electron microscope it is clear that intense activity would be much in evidence.

It should be emphasized that ion entry into roots is in large measure not simple diffusion since ions of a given species are frequently accumulated against concentration gradients, and therefore require an expenditure of energy to effect net inward transfer. The mechanism by which the energy released in root respiration brings about ionic accumulation has been the subject of intensive study by numerous investigators (5, 6, 7, 8). Broyer (20) has recently presented an excellent review of this subject.

Ion accumulation dependent upon expenditure of metabolic energy is conditioned by four primary variables: Ion supply, aeration, temperature, and supply of respiratory substrate—largely sugars. Robertson and Wilkins (7) have presented a diagrammatic schema based on Lundegardh's (6) concepts to suggest the mechanism that may be involved in the energetics of ion accumulation. A modified version of this schema is presented in Figure 1. It represents an infinitesimal section of the outer layer of the cytoplasmic membrane of an absorbing cell of a root.

During the respiration of the sugar that has been translocated to the root cells, carbon dioxide is released; but what is more pertinent to the theory of ion accumulation is the fact that during the respiratory sequence the enzyme dehydrogenase liberates free hydrogen. The carbon dioxide diffuses outwardly into the substrate presumably along concentration gradients. The released hydrogen becomes ionized to hydrogen ions with the freed electrons going to the cytochrome system reducing ferri-cytochrome to ferro-cytochrome. In other words, the ferri-cytochrome adjacent to respiratory activity oxidizes hydrogen to hydrogen ions while becoming reduced to ferro-cytochrome. Electrons are presumably surface-transferred along the reduced cytochrome to the absorbing surface of the cytoplasm. At the outward surface of the cell, oxygen diffusing inward is used to oxidize the ferro-

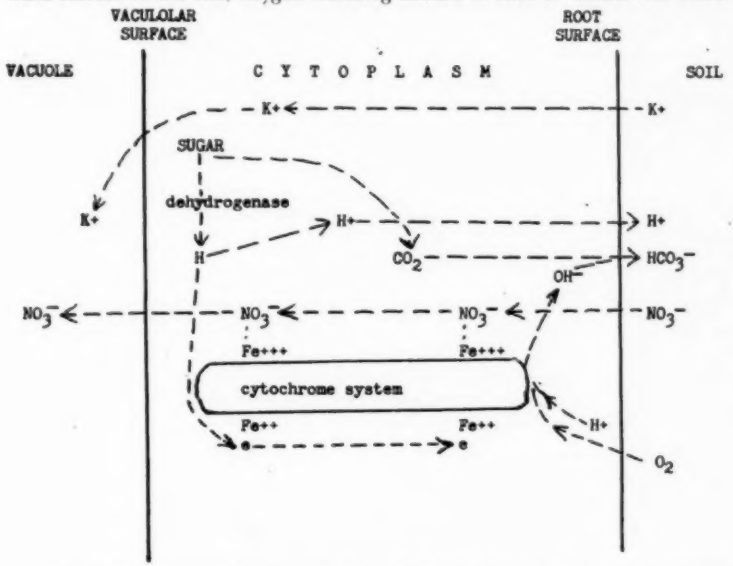

Figure 1. Schematic representation of the electron and anion transport system across the cytoplasmic membrane.

cytochrome by means of cytochrome oxidase. Hydrogen ions also enter the picture at this point with a release of hydroxyl ions. The oxidized ferri-cytochrome represents an increase in one positive valency for each ion atom oxidized. This added positive valency becomes a carrier for anions from the outer surface to the vacuolar surface where the cytochrome is reduced and the anion released to the vacuole. It is Lundegardh's concept that cations diffuse inwardly independent of energy released in order to maintain electrovent neutrality in the vacuole.

This brief mention of the postulated mechanism for the relationship between metabolism and ion accumulation is set forth to emphasize: (a) The utilization of sugar as the source of energy in nutrient accumulation, (b) the key demand for oxygen in the catabolic release of energy, and (c)

a favorable temperature for metabolic activity. These factors are of primary importance when water and nutrient supply is not limiting. It should also be mentioned that facilities for dissipation from the cell and root surface of carbon dioxide or bicarbonate ions produced by catabolism are essential for optimum root activity. An abnormal accumulation of bicarbonate in the substrate impairs the ability of tissue to accumulate ions (9).

It is evident in light of the foregoing that conditions inhibiting the transfer of sugar to the fibrous roots may also be detrimental, not only to root growth, but also to the capacity of roots to accumulate ions. Impaired carbohydrate synthesis or accumulation in the tops, pathogenicity of the phloem conductive tissue and low night temperatures may limit sugar transfer to the roots.

The temperature of the roots determines level of metabolic activity. If it is abnormally low, energy release from respiratory activity is low; and if it is abnormally high the rate of ground respiration may become sufficiently high to deplete the carbohydrate reserve. Physiologists distinguish between the ground respiration in root cells due to normal metabolic activity, and respiration associated with nutrient intake. When high temperatures of the roots result in carbohydrate depletion, there may be an inadequate supply of energy to effect ion accumulation.

The desirability of a well aerated soil for the vigorous development of beet roots is well recognized (10, 11, 12, 13), and oxygen demand of root as set forth in Figure 1 further emphasizes the essentiality of oxygen.

It is expedient to consider the soil conditions affecting oxygen supply at the roots. This may be done by reference to Figure 2 taken from the work of Gardner and Chatelain (19) depicting the relationship between the status of the moisture films about the soil particles and the hydrostatic head, i.e., vertical distance from the effective water table. At the water table all pores are filled with water, eliminating any channels for air transfer.

Hence, we find numerous observations to the effect that nearly saturated soils tend to asphyxiate roots. At just a few inches above the water table, only the largest pores are free of water, and most of the interstices are still filled with water. Gaseous transfer would be impeded, and, accordingly, there are many instances noted in which maintenance of soil moisture above filled capacity is inhibitive to plant growth. At a greater distance above the water table, the largest pores and many of the medium sized pores are free of moisture so that the contiguous air passages prevail. At this point, which we may regard as a moisture content slightly below field capacity, the moisture films are still sufficiently large and contiguous to maintain an abundant supply of water to the roots.

When we proceed to greater distances above the water table, approaching conditions supposedly corresponding to the permanent wilting percentage, the pore spaces are sufficiently free of water to provide excellent gaseous transfer; but the moisture films are so thin and confined to the smallest interstices that contact of rootlets with these films may be impaired, in addition to the fact that the energy retention of the moisture in the fine interstices may restrict movement of water molecules into the roots. That is, Figure 2 presents a clear picture as to the manner in which moisture content of soil affects aeration. The effect of soil status on gaseous transfer

was emphasized since Raney (14) has shown this to be the primary consideration in evaluating aeration of soils.

Absorption of moisture and nutrients is the primary physiological function of roots, and it follows that the efficiency with which the roots may accumulate water and nutrients from the soil mass will be contingent upon the extent to which the roots proliferate and contact the minute soil particles.

It was previously mentioned that Dittmer (3) estimated that the roots of a single rye plant exposed a surface of about 7,000 square feet when grown in a single cubic foot of loam soil. Such a soil may have a specific surface of around 20 square feet per cubic centimeter, so that the cubic foot of soil used by Dittmer had a total particle surface of around 500,000 square feet.

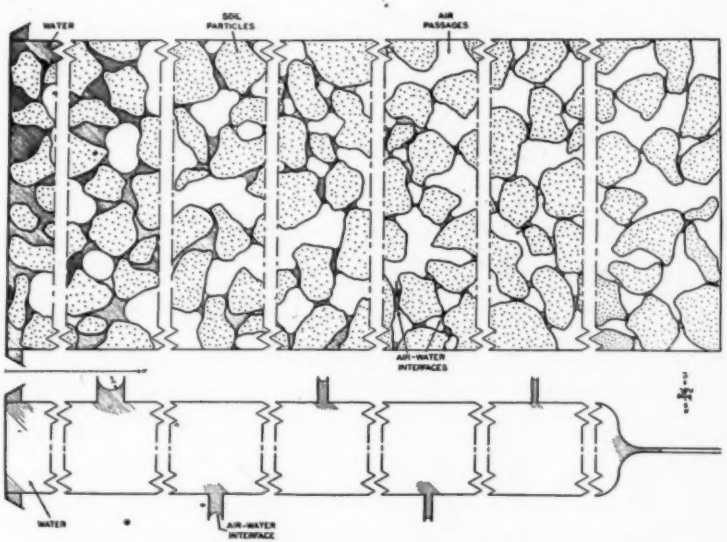

Figure 2. Diagram illustrating the change in air-water interface with increasing hydrostatic head.

Since soil is completely interspersed with minute interstices, it is obvious that all the surface of a root system is not exposed to soil particles; but some of the root surface is contiguous with air space. Thus, we find that less than 0.2 percent of the soil surface in Dittmer's culture was in direct contact with roots. This means that, for effective utilization of moisture and nutrients in the soil mass, there must be a certain degree of surface flow of these entities over soil particles to root surfaces. This situation may be more readily apparent on discussion of Figure 2.

In this microscopic picture of a soil presented in Figure 2, we note that the soil particles are pictured so as to show an abundance of minute air spaces among them. If we look at the section of this diagrammatic soil

at the moisture condition just above the water table, we note that the soil particles could be packed more densely, and also that there would be plenty of moisture present to lubricate and facilitate particle transfer to the more dense packing. Accordingly, we frequently find that mechanical agitation of wet soils transfers them into a "puddled" conditions. In this stage, the more closely packed particles in the "puddled" state contribute to lowered facility for gaseous transfer, more mechanical resistance to root penetration, and lowered capacity for storing available water. Consequently, plant growth may be seriously weakened (15, 16).

There are numerous instances where adverse physical condition of the soil has been shown to be a serious limiting factor in the growth of sugar beets (*loc. cit.*). Even though it is well recognized that beets respond to improved tilth in soils, this fact needs further emphasis in the light of modern tendencies to use heavy machinery during certain operations. This is especially the case during harvests on exceedingly wet soils. As studies by Gliemeroth (17) have shown, use of tractors and heavy machinery under such conditions may have seriously adverse effects upon the soil.

The Experiment Station of the Hawaiian Sugar Planters' Association (18) has recognized the seriousness of this problem. It is conducting soils engineering tests on the important soil types to determine the "fluid flow" zone of the compaction curve, so that the heavy Tournahaulers will not be used on the soils when they are in a sufficiently moist state to be seriously damaged by this heavy mechanical equipment.

Although the importance of good soil tilth for the production of sugar beets has long been recognized, current information on the physiological processes in roots and the danger of the adverse effects on soil from the use of heavy equipment emphasize the need for continually watching the factors affecting healthy roots.

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The Beet Sugar Industry

A. W. Skuderna[1]

Much has been written relative to various sugar beet agronomic practices calculated to increase beet tonnage and sugar per acre yields. In considerable part the proceedings of our society contain excellent papers on the production phases of the sugar beet crop. In general they deal with tests concerned with sugar beet varieties, organic and commercial fertilizers, field practices, time and rate of planting, width of row preferences, population studies, frequency and method of irrigation, insect and disease control and other equally important field practices involved in the production of sugar beets. Much progress has been made in increasing the national average of tons beets per acre yield. Similarly, there has been an increased sugar per acre yield, primarily due to increased tonnage beet yield.

While these significant changes have been taking place they have been also accompanied by equally significant downward trends in pounds of extractable sugar from one ton of beets sliced. As an illustration, one factory district whose annual beet production is well above 225,000 tons beets shows the following average performance for the prewar five year period 1936 to 1940 inclusive and the postwar five-year period 1946 to 1950 inclusive.

Table 1.—Comparison of Two 5-Year Periods in Production and Extraction of Sugar Per Acre.

	Tons Beets Per Acre	Percent Sugar Beets Bought	Pounds Extracted Sugar Per Ton Sliced	Sugar Per Acre Pounds Bought	Sugar Per Acre Pounds Extracted
1936-1940	16.81	18.14	303.7	6098	5105
1946-1950	21.16	16.32	255.1	6906	5398
Difference	+ 4.35 tons	— 1.82%	— 48.6 lb.	+ 808 lb.	+ 293 lb.

These averages show some very significant trends. While the yield of beets increased 25.8 percent during the last five-year period, the percentage of sucrose in the beet decreased 10 percent and the extractable sugar from a ton of beets was lowered 16 percent. And despite the 4.35 tons beets per acre increase, the quantity of sugar extracted from an acre of beets was increased by only 293 pounds or 5.74 percent, and which is less than the average pounds extracted from one ton of beets in the prewar 1936-1940 period. Considering the production and harvesting costs of this extra beet tonnage, it is readily apparent that there is much improvement needed because the sugar beet, as a commercial crop, has value only in proportion to the recoverable sugar. This has been recognized by the administrators of the Sugar Act in reducing the estimated quantity of recoverable sugar used as a basis in determining the conditional payments under the Act to sugar beet growers.

The causes for this lowered quality of the beet are several. Probably the first and foremost to consider is the development of sugar beet varieties which are heavy feeders on available plant food, requiring a longer growing

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season and which are of generally lower sucrose and purity values than those varieties which have earlier maturing qualities but which produce significantly lower tonnage yields of beets per acre.

Further, the heavy yielding varieties generally accumulate larger quantities of sodium and other harmful elements which depress purity and reduce the recoverable sugar from a ton of beets. Since the beet purchase contracts are based on the ability of recovering a certain amount of sugar from a ton of beets of given quality, it follows that unless these downward trends are arrested a revamping of the price structure may be necessary.

Another factor contributing to the production of lower quality beets stems from the excessive use of nitrogen. In some areas, notably in certain beet growing localities in California, the only field response obtained is from nitrogen.

The research staff of the American Crystal Sugar Company has for many years been endeavoring through numerous field tests to impress upon its growers the need for more moderate use of nitrogen beet fertilizers and more timely application of them, preferably by applying them immediately after planting. The unit of plant food has been gradually decreased from 150 pounds of nitrogen to 75 pounds of nitrogen per acre, resulting in the production of practically the same amount of sugar per acre and certainly at a considerably lesser expenditure. It is evident that the whole matter of adequate yet balanced fertilization of beets needs to be re-examined and especially so with special reference to the particular sugar beet variety used and the type of commercial fertilizer applied.

A problem of overshadowing importance is that presently arising from the aftermath of mechanical harvesting of beets. Frequently, with a lapse of only an hour or so between harvest of the beet and its actual delivery from the field to the receiving station, the beet has small opportunity to dry out. Consequently, the tonnage yield per acre is greater but the percentage of sugar is generally less than were the beets harvested by hand.

This, as is well known, is quite different from the former practice common in the industry when hand harvest was the method used and the lifted beets lay quite frequently for several hours in the field or windrow before topping was completed. An additional loss in time was experienced before the beet was finally delivered by slower transportation, either to the beet receiving station or to the factory proper. In either of these latter cases, there was considerable loss in yield through dessication but with attendant increase in sugar percentage. Whether the fresher condition of the mechanically harvested beets arriving at the factory is balanced by virtue of the probable increased daily slicing rate is a highly debatable question when the increased transportation costs per hundred weight of sugar are considered. Suffice it to say that in most instances the cost sheet shows a markedly higher transportation cost per hundred weight of sugar since neither truck nor rail transportation differentiates in the cost of hauling lower testing beets as against those which are higher testing.

This then brings us to a practice concerning which something can be done in the improvement of beet quality. This lies in the direction of a

better job of beet harvest, in delivering a cleaner product free from weeds and trash, and in the insistence of an improved beet harvest which has as its objective a properly topped beet. Attention is called particularly to the need of a better job of topping since, with the rapid spread of mechanical harvest, "which is now well past 60 percent of the total United States crop" the quality of topping has steadily deteriorated so as to pose a real challenge to the industry. Field tests have been made repeatedly through the years on the effect of varying amounts of high topping as affecting the recoverability of sugar from the beets. The results through the years have been uniformly the same; namely, the higher the amount of crown tissue retained on the beet the lower the overall extraction of sugar due to an increase in the melassegenic properties.

Periodically, there come proposals relative to the utilization of the entire crown for sugar-making purposes. The object back of this proposal obviously is to so change the method of harvest that the beet is completely defoliated, the crown bud scalped lightly and the "residue" delivered to the factory for sugar making purposes. While it is true that there is some sugar in the crown tissue, it is of such small extractable value that the present basis of purchasing beets is not a fair or reliable means for purchasing this low value material.

Since the feed value of the beet tops is a significant portion of the total value of the crop it should be utilized in this manner, so that the soil will be enriched, whether through the organic matter as in green manure form or through livestock residue, and thus the true position of the beet is maintained through its significant after effects upon crops that follow.

Summary

It behooves the beet breeder to increase his efforts in the development of adapted beet varieties which are more efficient and selective in their utilization of plant food for the production of quality beets with a decreased non-sugar content.

Similarly, the agricultural engineer has his work cut out in the improvement of mechanical harvesting machines which will result in delivery of beets which are well topped, free from trash and weeds and have satisfactory mechanical performance.

In the constant directing of effort in the reduction of field expenditures involved in the production of the sugar beet crop, the agronomist must always keep in mind not only the production of sufficient raw product, but also the critical requirements of quality beets by the factory, if capacity slicing and most economical production of sugar are to result.

Last, but not least, improvement in production of quality beets must begin in the field. The grower after all is the sole arbiter as to the decision he wishes to make, or the course he wishes to pursue relative to recommended practices. Significant progress has been made in many respects. Much more is needed in others.

Modern Trends in Beet Sugar Operations

WHARTON K. GRAY[1]

After Mr. Tolman had been advised that the subject of this paper would be "MODERN TRENDS IN BEET SUGAR OPERATIONS," it seemed to me that it might be interesting to look up the dictionary definition of the word "TREND."

A dictionary by Noah Webster, dated 1846, defines the word "TREND" as "TO RUN; TO STRETCH; TO TEND; TO HAVE A PARTICULAR DIRECTION." A 1947 edition of the American college dictionary defines "TREND" as "THE GENERAL COURSE, DRIFT OR TENDENCY; THE TREND OF EVENTS." The change in definition over a period of 100 years seems to indicate that trends may be somewhat more difficult to detect now than they were, by definition, 100 years ago.

Recent advances in technology have provided the means for a more exacting appraisal of the economic consequences of equipment and processing changes. Thus, modern processors may be expected to devote more time to the study of new techniques to determine whether they will suit their particular requirements. Processors no longer order a packaged factory from a builder.

Because of divergent views, some of the "TRENDS" that will be mentioned may be considered to be modern developments or experiments, rather than being indicative of what may be sound future practice.

All will undoubtedly agree that rapidly increasing labor costs indicate the necessity for reducing the factory man-hours required per 100 pounds of sugar produced. Material costs have also increased. To meet these increased overall costs the industry has adopted three main lines of attack:

1. **Increasing each factory's capacity.**
2. **Developing more productive and efficient equipment, and**
3. **Searching for and adapting economical processing methods.**

Beet Handling and Storage

To meet the short harvest period imposed by climatic conditions, it is necessary to pile and store large quantities of beets. To minimize losses, piled beets are treated in various fashions to preserve them for protracted periods.

In areas where the beets may freeze, subsequently thaw and rot, the piles are sometimes heated with infra-red lamps or protected by covering with tarpaulins.

Frequently, piles are force ventilated with cool air varying in amount from 10 to 40 cubic feet of air per minute per ton of beets. Some have installed thermostatic controls to start the air circulation when the ambient temperature drops a few degrees below that of the average beet pile temperature.

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Some processors have investigated possibilities of whitewashing the exposed surface of the beets in railroad cars to reflect the sun's heat and reduce the rate of deterioration.

To reduce capital expenditure and provide more flexibility of harvest, there has been a recent trend to utilize portable pilers, rather than permanent dumps at outlying locations.

Mechanical harvesting has increased the quantity of rocks and trash delivered to the factories. This has resulted in the development of additional beet cleaning equipment.

Continuous Diffusion

Although covered by many articles, papers and spoken words in recent years, continuous diffusion continues to be one of the most important technical trends in the past decade. We doubt that there will be many, if any, future batch-type diffusion battery installations. One horizontal rotary tube type diffuser has made some headway in Europe, and a vertical tube type is under development there. The multiple cell, horizontal-type, is currently in favor here. The advent of the continuous diffuser has made it possible for many factories to overcome both the battery and evaporator bottlenecks, and factory throughput of beets has been increased as much as one-third with lower losses and decreased draft.

We do not mean to imply that continuous diffusion is all "peaches and cream." Foam, bacteria and corrosion problems are more prevalent in continuous diffusers. Foam, of course, can be combatted with surface-active, proprietary defoamer compounds, the costs of which may reach alarming proportions.

Bacteria, while probably not a greater problem than with batch-type batteries, have received considerable attention in continuous diffusers. Careful regulation of the diffuser temperatures plus use of formaldehyde or other agents will usually control bacterial action in the diffuser. Needless to say, combatting bacteria in diffusers can be expensive.

Natural low pH conditions of beet juices plus acid decomposition products of bacterial action frequently produce corrosion in portions of the continuous diffusers. This action can be met by using corrosion-resistant materials and by careful bacteria control, which in turn becomes a problem of economics.

Pulp-Drying, Storing, and Packing

There have been several new trends in the dried pulp field. Considerable experimental work has been done with a new style of drier which has found considerable acceptance in the alfalfa, citrus waste and similar industries.

This drier has an integral air-cooled cylindrical furnace followed by a three-pass drier section in which the outer shell remains stationary and the two inner shells rotate.

Rolling or chopping will increase the bulk density of dried beet pulp. In addition, rolling or chopping breaks up the interlocking curls of the pulp, thus making it more free flowing.

Several companies are now pelletizing dried beet pulp, and other installations are under construction. Dried beet pulp pellets are about 3/16 to ½ inch in diameter and ⅜ to ¾ inch in length and have a bulk density of about 40 to 55 pounds per cubic foot.

Carbonation

There has been little recent change in methods of carbonation in the U. S. beet sugar industry, but there has been some interest in the Wiklund process as practiced in Europe. This process is an attempt to couple the economies of the Dorr system with the presumably better juice qualities of the predefecation system.

Many factories are using settling aids in carbonation thickeners. Milk was once thought to be a settling aid, but the effect was not lasting. Derivatives of starch, seaweed and gums cover the various compounds presently used to improve the settling characteristics of the first carbonation precipitate.

There is a trend to use effective alkalinity as a measure of second carbonation control and as a guide to the proper addition of soda ash. Effective alkalinity can be briefly defined as the difference between the total alkalinity, as determined by acid titration to the 9.25 pH end point, and the soap test alkalinity. We understand, however, that the concept of effective alkalinity is not applicable to beet juices from certain areas of the country.

Filtration

There are efforts to convert processors back to direct filtration of first carbonation juice. This is based on the premise that it may be profitable to eliminate the slight juice degradation occurring in the thickener.

Many new filters of the auto-sluice variety are currently on the market. These filters combine the features of the Sweetland and the Kelly type filters, but generally use fine metallic cloth instead of cotton cloth.

New types of synthetic filter fabrics have appeared each year. Some of these are proving more economical than cotton fabrics, particularly on rotary drum vacuum filters in the Steffen house.

Although not particularly new, some organizations are using various papers to face their plate and frame filter cloths, to facilitate removal of the cake and thus extend the life of the cotton filter cloth.

Evaporation

The trend in evaporators is toward greater acceptance of the long tube vertical type over the calandria type. Both types have their inherent advantages, but with widespread acceptance of the L.T.V. evaporators in the pulp and paper industry, the cost of the L.T.V. evaporator has dropped below that of the calandria type. The use of higher pressure exhaust steam and greater utilization of vapors for process heating have further increased the economics of the long tube vertical evaporators.

Many evaporator installations have been completely instrumented for automatic control. This has eliminated the need for an evaporator operator.

Evaporator scaling continues to plague the industry. Alginates, alginates mixed with phosphates, and tetra-phospho-glucosates are a few of the proprietary scale-preventive chemicals currently used by a portion of the industry. The effectiveness of these treatments is not as clear-cut as it has been in the cane industry.

Sugar End Operations

Calandria pans and lower pressure steam (i.e., evaporator vapors) have gained widespread acceptance in sugar boiling practice.

Much work has been done on the crystallization and purging of raw fillmass. Low crystallization rates associated with low purities tend to produce a final fillmass of fine mixed grain. One company utilizes a footing taken from the intermediate fillmass, after graining, to use as a start for its low raw boiling. This system enables low raw sugars of 97 to 98 purity to be produced as compared to 89 to 92 purity under direct graining procedures.

Another company has developed a semi-automatic pan boiling apparatus based on boiling point rise in which the feed addition and temperatures are automatically controlled. Seeding is accomplished by dispersing powdered sugar in isopropyl alcohol which is injected into the pan at the proper moment as determined by the boiling point rise. This system is said to produce a final fillmass with uniform grain size. Final "Brixing" of the pan is determined by the power input to the fillmass circulating motor.

In recent years there has been a trend towards automatic direct-connected, electric motor-driven centrifugals. All phases of the cycle can be completely automatic including loading and unloading. Automatic unloading has resulted in general preference for deeper baskets.

Lime Manufacture

Few changes have occurred in this field. At the present time, to our knowledge, only two plants are reburning pond lime. One uses a rotary kiln, and the other uses a multiple hearth type furnace.

Ion Exchange

Investigations into the use of ion exchange in processing beet sugar continue. At the present time it is an added step to the existing process. Essentially, complete recovery of by-products will probably be necessary in order that ion exchange can compete economically with the present methods of processing. Research continues, and it is possible that use of ion exchange will expand.

Power and Steam Generation

The desired increase in plant capacity, together with obsolescence of existing equipment, has motivated many recent replacements in power generation facilities. The trend has been towards greater capacity, higher pressure boilers. Generally speaking, the trend is toward steam pressures of 300 to 400 psi which is expanded through turbine generators to exhaust steam pressures of 30 to 45 psi.

Electrical power is being generated at higher voltages, particularly 2,300 and 4,160 volts, for distribution to unit substations located at strategic points for transformation of the power to lower voltages for consumption. In many

instances this system will conserve copper, reduce voltage losses, and be less expensive than low voltage distribution. Motors of 200 HP. and larger are frequently operated directly on these higher voltages.

Rising fuel costs have centered attention on more efficient use of heat.

Instrumentation

Wherever there is a human factor, there is always the possibility of an error in judgment. As has been found in most other processing industries, if an instrument is available and applicable for a given control problem, it will frequently repay its investment through labor-saving and offer the additional reward of better process control.

Most of the unit processes in beet sugar manufacture lend themselves to automatic control, and much work has been accomplished in this field. However, at the present time, no effort has been made to coordinate automatically these separate operations. We predict that this will be an accomplished fact in the future.

Waste Disposal

Regulations concerning conservation of underground water supplies and anti-pollution laws are making reclamation or treatment of wastes necessary in some areas.

Steffen waste and pulp press water are the most difficult wastes to treat. The manufacture of mono-sodium glutamate from Steffen waste has solved the first problem.

Pulp waste has been reclaimed in a number of ways. One method involves partial liming, followed by sterilization with chlorine and thence returning to the diffusion battery. Others return directly to the battery without further treatment. Still others lime the press water, clarify in Dorr thickeners, cool and utilize this water in the Steffen house as a diluent for molasses. Other waste waters are screened and impounded for clarification and aeration prior to release.

Products

To meet competition offered by cane sugar refiners, some beet sugar producers have entered the specialty products field. Several companies now offer a line of special products which include fine grain granulated, confectioners' powdered, golden brown, instant dissolving, cubes, wrapped tablets, individual superfine packets, liquid sucrose, inverted syrups and bulk sugar. The manufacture of specialties has introduced new warehousing and shipping problems.

More industrial users are purchasing sugar in liquid and in bulk to effect in-plant savings.

Initially a large number of sleeve valve paper bags were used, but the recent trend, because of lower cost, is toward open mouth paper bags.

Working Conditions

While the industry has improved in all the aforementioned technological phases, the general working conditions have also improved. Lighting, ventilation, safety, and sanitary conditions in plants are being constantly improved.

AGRONOMY

Petiole Sampling of Sugar Beet Fields in Relation to Their Nitrogen, Phosphorus, Potassium and Sodium Status[1]

ALBERT ULRICH AND F. J. HILLS[2]

A technique for collecting petiole samples from sugar beet fields for nutrient assay has been used in California for several years (9, 11)[3]. This procedure appears to correlate well with observed growth differences and the results of field experiments, particularly with respect to nitrogen, the principal nutrient limiting yields (10). Aside from the work of Brown (1) in Colorado, there has been little emphasis on the size of sample necessary to estimate with sufficient accuracy the nutrient status of a given field for practical fertilizer recommendations.

With the increasing use of petiole analysis, it seemed desirable to investigate more thoroughly the sources of variation involved in this procedure and, if possible, to improve the overall technique. The procedure used until now to collect petiole samples from commercial fields in California has been described (8). Briefly, it consists of dividing the field to be sampled into equal parts of approximately 10 acres or less; walking across each section at right angles to the rows and collecting 30 to 40 petioles at equally spaced intervals. Fields up to 40 acres in size are represented by four samples each and larger fields by more, each 10 acres being represented by a separate sample.

Procedure

Over a three-year period, 17 different fields were selected for petiole sampling in the following counties: eight in Yolo, five in Monterey and four in Kern. Each field was sampled by collecting individual petioles at uniform intervals while walking across the rows in the middle of a 10-acre area. Such an area would normally constitute a sampling unit from which 30 to 40 petioles would be taken. Each petiole selected for analysis was from a leaf defined by Ulrich (8, 9) as "a youngest mature leaf."

In three of the fields four petioles were collected at each of 25 locations. At each location two of the petioles were taken from the same plant and two taken from another plant located within a few feet of the first. In the remaining fields 25 petioles were taken at equally spaced intervals.

The petioles were bagged separately in the order of their collection, dried, ground and analyzed for nitrate-nitrogen (5, 8), phosphate-phosphorus (8), and sodium. After the plant material had been ashed as previously described (8), the ash was taken up in nitric acid (0.16N, final concentration) and analyzed for potassium and sodium by the lithium internal standard method for a flame photometer (Perkin-Elmer, Model 52A). Two determinations, one on one day and the other on another day, were made on each petiole.

The results of the petiole analyses were analyzed statistically by the usual methods of analysis of variance. The components of variance, variance of a single determination, confidence limits and coefficients of variation

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[3] Numbers in parentheses refer to literature cited.

were determined by the procedures outlined by Brownlee (2), Cochran and Cox (4) and Snedecor (6). Specific examples of the calculations are given as footnotes to Table 2.

Results of Intensive Sampling

The components of variance associated with petiole sampling of sugar beet fields, expressed as percentages of the total variation, are given in Table 1 for the nitrate, phosphate, potassium, and sodium determinations of three fields sampled intensively. Of the two main sources of variation in the field and in the laboratory, those in the field, as expected, greatly exceeded the variations in the laboratory. Within the field, surprisingly enough, the variations from petiole to petiole within a beet exceeded those from beet to beet or from location to location, particularly the nitrate determination of field HY. Large variations between petioles within a beet also appeared in the other fields in the nitrate, phosphate, potassium and sodium determinations. Surprising, too, was the fact that in some instances there was no significant component of variation for locations within a field, which indicated that the variations from beet to beet within a location were as great as those of locations within a field.

The components of variance of the chemical analyses of the petiole samples were minute compared to the components of variation within the field. In all instances, except for nitrate-nitrogen in field HY, the analytical variation was less than 2 percent of the total variation, sampling plus analysis. Within the analytical variations the component between dates was significant in most cases, but this constituted less than half the total analytical variation of the nitrate determination, except in field HY where the variation for analysis was exceptionally large. With the possible exception of nitrate analyses made of high-nitrate samples, there is little to be gained from further improvements in analytical methods to increase the precision of petiole sampling of sugar beet fields. This conclusion is supported by the results of sampling 14 more fields in Yolo, Monterey and Kern counties in which the variations of field sampling and of laboratory analysis are compared (Tables 2, 3, 4 and 5).

Since the components of variation between petioles within a beet and between beets within a location proved to be highly significant in all cases, this might imply that the order of selecting two petioles from a single beet or from two adjacent beets could be important in the petiole sampling of sugar beet fields. Once a leaf is selected from a plant, the second leaf selected might conceivably be less desirable for analysis than the first. Similarly, once a beet is selected for sampling within a location, the second beet might differ consistently in some significant manner from the first. Considering these as possibilities, statistical analyses were made of the results of the first petiole compared with the second petiole of each beet, and of the petioles of the first beet with the second beet. These proved to be nonsignificant. Apparently, there is no consistent pattern followed by a field man in selecting the first beet to be sampled or in selecting the first petiole on a beet for analysis. This conclusion, however, may not be true of all field men or of all fields to be sampled.

Table 1.—Components of Variance as Percent of Total Variance for Nitrate, Phosphate, Potassium and Sodium Determinations for Dried Petioles of Recently Matured Leaves.

			Components of variance[3] as percent of total							Total variance[2]
							Analytical			
Field[1]	Constituent	Mean	Between locations (within field) S_L %	Between beets (within location) S_B %	Between petioles (within beets) S_P %	Total between petioles (within field) S_{LBP} %	Between dates S_t %	Residual S_A %	Total between analyses S_{tA} %	S^2_T
H Y	NO_3-N	19,600 (ppm)	18.6[4]	17.5[4]	41.7[5]	77.8[5]	14.9[5]	7.3	22.2	95,500
B Y	NO_3-N	2,227 (ppm)	0	82.2[5]	17.1[5]	99.3[5]	0.0	0.8	0.8	39,495
HD Y	NO_3-N	2,164 (ppm)	45.6[5]	39.8[5]	14.2[5]	99.6[5]	0.08[5]	0.26	0.34	53,007
H Y	PO_4-P	1,918 (ppm)	0	57.3[5]	40.7[5]	97.9[5]	0.5[5]	1.6	2.1	3,779
B Y	PO_4-P	1,011 (ppm)	54.6[5]	15.3[5]	22.2[5]	98.6[5]	0.0	1.4	1.4	1,527
HD Y	PO_4-P	1,848 (ppm)	0	68.6[5]	29.6[5]	98.2[5]	0.5[5]	1.4	1.8	5,173
H Y	K	4.77 (%)	44.7[5]	40.4[5]	13.3[5]	98.4[5]	0.5[5]	1.1	1.6	0.6484
B Y	K	3.06 (%)	36.6[4]	49.0[5]	12.1[5]	97.7[5]	0.6[5]	1.7	2.3	0.6520
HD Y	K	4.44 (%)	28.2[4]	52.5[5]	17.8[5]	98.5[5]	0.0	1.5	1.5	0.6567
H Y	Na	5.11 (%)	55.5[5]	16.7[5]	26.6[5]	98.8[5]	0.2[5]	1.0	1.2	0.9068
B Y	Na	3.67 (%)	0	85.5[5]	13.0[5]	98.6[5]	0.06[4]	1.4	1.4	1.5223
HD Y	Na	1.87 (%)	55.6[5]	26.6[5]	17.0[5]	99.2[5]	0.0	0.8	0.8	0.5310

[1] See Table 2 for field designations.
[2] Total variance values for NO_3-N and for PO_4-P have been multiplied by 1/100.
[3] Components of variance were calculated according to procedure by Brownlee (2).
[4] Significant at the 5% level.
[5] Significant at the 1% level.

Results of Extensive Sampling

Although the intensive sampling of three sugar beet fields, involving 2,400 separate chemical analyses, showed conclusively that the bulk of the variation in petiole sampling was in the field rather than in the laboratory, more information about the nature and extent of the field and laboratory variations seemed desirable. For this study a single petiole from each of 25 locations in a field were taken at equidistant intervals across the plant rows in five more fields in Yolo county, five in Monterey county and four in Kern county. Each petiole was analyzed for the same constituent on two different days: nitrate-nitrogen, phosphate-phosphorus, potassium and sodium. The analytical results of these fields along with those of the three original fields intensively sampled are given in Tables 2, 3, 4 and 5.

Nitrate-Nitrogen

The results tabulated in Table 2 give the ranges in nitrate-nitrogen values, the confidence limits of the mean, the components of variance, the gains in precision of different numbers of petioles per sample and times of analysis, the variances of single determinations and the coefficients of variation of each field. Of particular interest in Table 2 is the wide range in nitrate-nitrogen values from field to field and within fields. For example, in field HY the average value is 19,600 ppm., the highest 28,400 and the lowest 13,700. If the critical petiole nitrogen concentration at which a response to nitrogen fertilization may be expected is 1,000 ppm. on a dry basis, then the entire field in HY is amply supplied with nitrogen at the time the petiole samples were taken. Proceeding down the list and judging by the mean values alone, all fields are adequately supplied with nitrogen except field 10Y. Logically, though, nitrogen adequacy would decrease with a decrease in the mean nitrogen values. Thus, mean values of less than 3,000 ppm. nitrate-nitrogen would be considered as approaching the danger line and additional petiole samples should be taken frequently if an adequate supply of nitrogen is to be maintained within the beets at all times. Experience has shown that once the nitrate-nitrogen values fall below a mean value of 1,000 ppm., the beets grow less than those above this value (10).

Decisions as to the desirability of adding nitrogen to a field of beets must also consider the degree of reliability or confidence which may be placed in mean values obtained by petiole sampling. When nitrate values are determined from samples consisting of 25 petioles and one analysis, the decision to observe or not to observe a field more closely is influenced by the variability of the individual plants in the field. This is definitely true for fields in Kern county where the petiole samples were collected from fields which were obviously spotty as shown by visual observations, by petiole tests in the field for nitrate with diphenylamine reagent (7), and finally by the chemical analysis of the petioles themselves.

The great importance of the individual petiole nitrate values was not fully realized until the laboratory analyses for nitrate were completed and tabulated. Thus, similar mean nitrate values of different fields reflected entirely different distributions of the petiole nitrate values in the field, as in fields 13 K and 7 Y. In field 13 K, which had a mean value of 4,130, 36 percent of the beets sampled were below 1,000 ppm., and field 7 Y, which had a lower mean value, 3,610 ppm., had only 8 percent of the

Table 2.—Nitrate-Nitrogen in Petioles Expressed in Parts Per Million on a Dry Basis for 17 Sugar Beet Fields as Related to the Ranges of Values, Confidence Limits, Components of Variance, Variances of Single Determinations, Gains in Precison and Coefficients of Variation.

Field[1]	Range	Mean	Confidence limits at the 5% level[3] — Limits of error: One analysis, Petioles per sample: 25	50	Two analyses, Petioles per sample: 25	50	Components of variance (multiplied by 1/100): Between petioles within field S^2_{LBP}	Analytical: Between dates S^2_t	Residual S^2_A	$S^2_{LBP}/S^2_T \times 100$	Variance[2] single analyses x 1/100: petioles 25	Gain in precision: Single analysis petioles[4] 50	Duplicate analyses petioles[5] 25	C.V.[6]
	ppm.	ppm.	ppm.	ppm.	ppm.	ppm.				%		%	%	%
H Y	28,400—13,700	19,600	±3,050	±2,954	±2,283	±2,155	74,300	14,200[8]	7,000	77.8	24,172	3.2	33.6	7.9
I M	19,800— 8,900	13,606	±2,707	±2,577	±2,058	±1,915	89,300	114[8]	41	85.2	19,070	5.0	29.8	10.2
V M	15,800—10,400	13,110	±1,108	±1,037	± 876	± 783	19,900	0	24	89.2	3,196	6.8	26.5	4.3
VIII Y	22,100— 1,400	9,078	±2,040	±1,544	±1,964	±1,442	231,140	0	1,585	99.3	10,831	32.1	3.9	11.5
IV M	10,900— 1,520	5,350	± 995	± 771	± 943	± 703	51,395	182[8]	338	98.9	2,576	29.1	5.5	9.5
III M	10,900— 520	4,760	±1,177	± 857	±1,159	± 832	84,660	0	219	99.7	3,605	37.3	1.6	12.6
XIII K	19,400— 170	4,130	±2,058	±1,483	±2,038	±1,455	265,048	0	421	99.8	11,023	38.8	1.0	25.4
XIV K	11,400— 150	4,042	±1,295	± 940	±1,278	± 916	103,487	27[7]	201	99.8	4,368	37.8	1.3	16.4
VII Y	8,100— 680	3,614	± 875	± 640	± 859	± 619	46,315	0	140	99.7	1,993	36.7	1.9	12.4
IX Y	8,450— 290	3,529	±1,082	± 783	±1,069	± 765	72,466	0	145	99.8	3,044	38.2	1.2	15.6
II M	7,200— 470	2,984	± 822	± 621	± 793	± 581	37,821	94[8]	152	99.3	1,759	32.4	3.7	14.0
XII K	9,800— 140	2,458	±1,039	± 778	±1,007	± 735	61,810	0	339	99.5	2,811	33.5	3.2	21.6
XI K	9,200— 480	2,271	± 781	± 570	± 768	± 552	37,026	0	106	99.7	1,587	37.0	1.7	17.5
B Y	11,150— 190	2,227	± 848	± 646	± 813	± 600	39,146	0	305	99.2	1,871	31.3	4.3	19.4
HD Y	11,150— 220	2,164	± 939	± 690	± 920	± 664	52,826	45[8]	136	99.6	2,294	36.1	2.1	22.1
VI Y	4,080— 250	1,374	± 458	± 336	± 450	± 324	12,671	14[8]	26	99.7	547	36.3	1.8	17.0
X Y	540— 70	215	± 88	± 80	± 73	± 63	181	0	13	93.3	20	10.2	21.3	21.0

[1] M = Monterey, Y = Yolo, K = Kern County.

[2] Variance of a single determination on a composite of 25 petioles = $S^2_{LBP}/25 + S^2_A + S^2_t$, e.g., 74,300/25 + 14,200 + 7,000 = 24,172; for duplicate analyses on composite of 50 petioles = $74{,}300/50 + \frac{(14{,}200 + 7{,}000)}{2} = 12{,}086$. The values given in the table have been multiplied by 1/100.

[3] Confidence limits = mean ±t (Variance of technique)½, *e.g.*, for single analysis on composite of 25 petioles, 19,600 ± 1.96 (24,172)½ = 19,600 ± 3,050; for duplicate analyses on composite of 50 petioles, 19,600 ± 1.96 (12,086)½ = 19,600 ± 2,155.

[4] Using the limit of error for single analysis, 25 petioles composited, as 100%; the gain in precision for a 50-petiole sample, one analysis, equals 3,050 ÷ 2,954 x 100 = 103.2% or a gain of 3.2%.

[5] Gain in precision for duplicate analyses, 50 petioles, equals 41.4% for all fields.

[6] Coefficient of variation (C. V.) = (Variance for single analysis, 25 petioles composited)½ ÷ mean x 100.

[7] Significant at the 5% level.

[8] Significant at the 1% level.

beets below 1,000 ppm. Accordingly, for greater precision in judging the nitrogen status of a field of beets, the testing of individual plants or at least observing them closely in the field should be encouraged, particularly in areas sampled for the first time.

A review of the confidence limits of the nitrate means in relation to the number of petioles taken per sample and to the number of times each sample is analyzed is informative. On the average, more precision is gained by taking more petioles in the field rather than by making more analyses of the same sample in the laboratory. Only when the nitrate values are exceptionally high is there an appreciable gain in precision by making duplicate analyses of the same sample. In no case does this gain in precision by more analyses of high-nitrate samples have an effect on the interpretation of the results. Even when the number of petioles taken for a sample is doubled the maximum gain in precision in any one field is less than 40 percent. This improvement in precision, however, occurs mainly in the low-nitrate samples when an increase in precision is highly desirable, so more petioles per sample should be taken in the field whenever possible.

Still more important for an accurate evaluation of the nutrient status of a field of beets, however, is the taking of more samples from the same field; for example, one from each quarter section of a field. This yields much more useful information than the collection of 50 petioles per sample with two analyses per sample, because in the taking of more samples per field a measure of the variation of the plants in each field is obtained, an important consideration in the selection of a fertilizer program for a field of sugar beets.

The components of variance found in the 14 fields sampled extensively agree with the findings for the three sugar beet fields sampled intensively. Again, most of the variations are from petiole to petiole in the field and not in the laboratory analyses. The coefficients of variation indicate considerable variation in this statistic from field to field but there is no consistent trend in the values which might offer a better treatment of the results in the present sampling technique studies.

Phosphate-Phosphorus

The range in phosphate-phosphorus values of the 17 fields recorded in Table 3 differs just as strikingly as the nitrate values already discussed. If the critical phosphate-phosphorus concentration in the dry petioles is taken to be 750 ppm., then only one field has an average value below this figure, even though all but six fields sampled have some petioles considerably less than this value. If the phosphate-phosphorus value of the 17 fields should have been found at the lower confidence limit for each mean, this would have changed the interpretation of the phosphorus status of only one field; namely, field 8 Y, from a low phosphorus status to one that is below the critical concentration. At the upper confidence limit the single field now below the critical concentration would be just above the critical phosphate-phosphorus concentration. In either case the beets would be classified as low in phosphorus, and methods of raising the phosphorus levels within the plants would be considered carefully, particularly if later samplings should show further declines in phosphorus status.

Deciding whether or not to fertilize a field of beets with phosphorus on the basis of a single sample may not be justified unless the variability

Table 3.—Phosphate-Phosphorus Expressed in Parts Per Million on a Dry Basis for 17 Sugar Beet Fields as Related to Ranges of Values, Confidence Limits, Components of Variance, Variance of Single Determinations, Gains in Precision and Coefficients of Variation.

Field[1]	Range	Mean	Confidence limits at the 5% level[2]				Gain in precison		Components of variance (multiplied by 1/100)				Variance[2] single analysis x 1/100	C.V.[3]
			Limits of error				Single analysis	Duplicate analyses	Between petioles within field	Analytical				
			One analysis Petioles per sample		Two analyses Petioles per sample					Between dates	Residual			
			25	50	25	50	50 petioles[1]	25 petioles[2]	S^2_{LBP}	S^2_t	S^2_A	S^2_{LBP}/S^2_T x 100	25 petioles	
	ppm.	ppm.	ppm.	ppm.	ppm.	ppm.	%	%				%		%
IV S	3,900— 950	2,003	±296	±229	±282	±210	29.7	5.3	4,595	12[a]	33	99.0	229	7.5
I S	2,970—1,250	1,975	±200	±174	±173	±142	14.9	15.6	1,286	0	53	96.0	104	5.2
H W	3,530— 790	1,918	±295	±242	±268	±208	21.9	9.9	3,701	19[a]	59	97.9	226	7.8
II S	3,070— 750	1,880	±250	±205	±228	±177	22.0	9.6	2,672	9[a]	47	97.9	163	6.8
HD W	3,090— 460	1,848	±265	±215	±243	±187	23.3	9.1	3,115	15[a]	43	98.2	183	7.3
XII K	3,440— 980	1,769	±210	±156	±204	±148	31.3	5.0	2,539	0	13	99.5	114	6.0
III S	2,620— 900	1,765	±346	±323	±274	±245	7.1	26.3	1,992	100[b]	132	89.6	312	10.0
XIII K	2,890— 600	1,572	±251	±182	±248	±177	37.9	1.2	3,892	0	8	99.8	164	8.1
XI K	2,830— 350	1,552	±252	±189	±244	±178	33.3	3.3	3,608	5[a]	15	99.4	165	8.2
V S	2,350— 920	1,525	±159	±126	±148	±112	26.2	7.4	1,216	0	17	98.6	66	5.3
IX W	2,500— 440	1,480	±259	±207	±241	±183	25.0	7.9	3,156	27[a]	22	98.5	175	7.2
X W	2,570— 410	1,175	±281	±233	±255	±199	20.6	10.2	3,287	0	75	97.8	206	12.3
VII W	1,860— 440	1,116	±167	±132	±157	±118	26.5	6.4	1,371	0	18	98.7	73	7.6
VI W	2,190— 430	1,035	±250	±224	±208	±177	11.4	19.8	1,584	48[a]	51	94.1	162	12.3
B W	2,130— 430	1,011	±177	±140	±165	±125	26.4	7.5	1,506	0	30	98.0	81	8.9
VIII W	2,010— 370	844	±187	±141	±181	±133	32.6	3.3	1,978	0	12	99.4	91	11.3
XIV K	1,980— 280	642	±169	±123	±167	±120	37.4	1.2	1,753	0	4	99.8	75	13.4

[1] [2] [3] [4] [5] [6] [7] [8] For explanation see Table 2.

of the phosphorus status of the beets within the field is also known. Just as in the nitrate-nitrogen values, similar mean values were observed for different ranges in phosphate values. In field 13 K, with a mean value of 1,572, 12 percent of the petioles were below the critical concentration, while in field 5 M, with an average value of 1,523, no values were below the critical concentration. Thus, the likelihood of an increase in average yield in field 13 K is better than in field 5 M. Again, it should be emphasized that in fields sampled for the first time a measure of the within-field variation should be obtained in order to evaluate the likelihood of response to phosphatic fertilizers. Timing is also important in the successful fertilization of beets, particularly the stage of development of the plants at the time of the deficiency, the duration of the deficiency and the timing of the fertilizer applications.

Increasing the number of petioles taken per sample from 25 to 50 appreciably decreased the limits of error of the mean, while increasing the number of analyses per sample from one to two just slightly decreased these limits. The gain in precision of a 50-petiole sample over a 25-petiole sample was approximately 25 percent, duplicate analyses over a single analysis 9 percent, and for both a 50-petiole sample and duplicate analyses, 41 percent.

The components of variance, just as for nitrate, were made up mostly of variations from petiole to petiole in the 25 locations in the field and not from the variations of analysis in the laboratory, except in field 3 S. Even in this field the component of variation for analysis was only 10.4 percent of the total variation, in contrast with an average variation of 1.7 percent in the remaining fields. The coefficients of variation on the average were considerably less than those of the nitrate determination.

Potassium Analyses

The potassium values of the individual petioles also differed greatly from each other (Table 4). The highest potassium value, 11.44 percent, was observed in field 10Y and the lowest, 0.76 percent, observed in field 4 M. The means of these fields ranged from 7.26 percent to 1.50 percent. If the critical potassium concentration at which a response to potassium fertilization may be expected is tentatively set at 1.00 percent, then none of the fields sampled was below this value. Individual petioles in field 4 M, however, were below the 1.00 percent level in 16 percent of the petioles sampled. If potassium is added to this field and the increased growth in the deficient beets is large enough to give a significant increase in yield for all the beets in the field, deficient and non-deficient, then a higher mean potassium value is indicated at which a response may be obtained under field conditions. Thus, the interpretation of the mean values of field samples could well depend upon the degree of variation of the beets sampled. Critical concentrations of fields of uniform beets would be lower than those of fields with highly irregular beets.

The limits of error of the mean potassium values (Table 4) are so small that no change in the interpretation of the results appears necessary, even if the mean values are taken at the lower confidence limit. At the higher confidence limit the interpretation of the mean values also remains the same since none of the values is below the 1.00 percent level. Again, the

Table 4.—Potassium in Petioles Expressed in Percentages on a Dry Basis for 17 Sugar Beet Fields as Related to Ranges of Values, Confidence Limits, Components of Variance, Variance of Single Determinations, Gains in Precision and Coefficients of Variation.

Field[1]	Range	Mean	Confidence limits at the 5% level[3]				Gain in precision		Components of variance (multiplied by 1/100)			S^2_{LBP}/S^2_T x 100	Variance[2] single analysis x 1/100	C.V.[9]
			Limits of error				Single analysis	Duplicate analyses	Between petioles within field	Analytical				
			One analysis Petioles per sample		Two analyses Petioles per sample		50 petioles[4]	25 petioles[5]		Between dates	Residual		25 petioles	
			25	50	25	50			S^2_{LBP}	S^2_t	S^2_A			
	ppm.	ppm.	ppm.	ppm.	ppm.	ppm.	%	%				%		%
X Y	11.44—4.85	7.26	±0.70	±0.55	±0.66	±0.50	27.1	6.6	2.4228	0	0.0303	98.8	0.1272	4.9
XIV K	8.70—4.08	6.55	±0.52	±0.41	±0.49	±0.37	28.0	5.9	1.3979	0.0022[7]	0.0134	98.9	0.0715	4.1
H Y	7.12—3.10	4.77	±0.37	±0.30	±0.34	±0.26	24.4	8.1	0.6380	0.0030[8]	0.0074	98.4	0.0359	4.0
VI Y	6.00—2.80	4.48	±0.42	±0.35	±0.37	±0.30	18.5	12.7	0.6524	0.0091[8]	0.0101	97.1	0.0453	4.8
HD Y	6.86—2.70	4.44	±0.37	±0.30	±0.35	±0.26	24.9	7.5	0.6467	0	0.0098	98.5	0.0359	4.3
VII Y	6.75—3.20	4.31	±0.37	±0.30	±0.33	±0.26	21.5	10.2	0.5613	0	0.0125	97.8	0.0350	4.3
XIII K	6.44—2.37	4.16	±0.46	±0.37	±0.43	±0.33	25.2	7.6	1.0052	0.0024[7]	0.0129	98.5	0.0555	5.7
XII K	6.90—1.58	4.05	±0.49	±0.39	±0.46	±0.35	27.0	6.6	1.2107	0.0037[8]	0.0115	98.8	0.0636	6.2
IX Y	6.36—2.32	4.04	±0.41	±0.31	±0.39	±0.29	31.9	4.1	0.9236	0	0.0066	99.3	0.0435	5.2
II M	4.82—2.78	3.84	±0.24	±0.19	±0.22	±0.17	27.3	6.7	0.2770	0	0.0036	98.7	0.0147	3.2
VIII Y	6.66—2.12	3.77	±0.44	±0.32	±0.43	±0.31	37.6	1.6	1.1963	0	0.0031	99.7	0.0510	6.0
XI K	6.28—1.06	3.09	±0.50	±0.38	±0.49	±0.36	33.2	3.3	1.4359	0.0030[8]	0.0054	99.4	0.0658	8.3
B W	5.25—1.10	3.06	±0.39	±0.33	±0.36	±0.28	20.9	10.7	0.6371	0.0040[8]	0.0109	97.7	0.0404	6.6
III M	4.33—1.42	2.99	±0.34	±0.26	±0.33	±0.24	30.3	4.8	0.6250	0	0.0054	99.1	0.0304	5.8
I M	4.22—1.61	2.71	±0.29	±0.22	±0.27	±0.20	28.3	5.9	0.4140	0	0.0046	98.9	0.0213	5.4
V M	2.50—1.13	1.73	±0.19	±0.16	±0.15	±0.13	12.1	18.6	0.0891	0	0.0053	94.4	0.0089	5.5
IV M	2.42—0.76	1.50	±0.23	±0.19	±0.21	±0.17	21.2	9.9	0.2331	0.0012[8]	0.0038	97.9	0.0143	8.0

[1 2 3 4 5 6 7 8] For explanation see Table 2.

gains in precision are increased by taking more petioles per sample than by making duplicate analyses of either a 25- or 50-petiole sample. Apparently, by using a flame photometer the analysis of the plant material for potassium and for sodium is so precise that little is gained by making more analyses of the same sample. This fact and the low coefficients of variation of a single analysis of a 25-petiole sample again indicate that more useful information about the nutrient status of a field of beets would be gained by analyzing individual petioles or by taking more 25-petiole samples than by taking more petioles per sample.

Sodium Analyses

The recent interest in the sodium content of beets as a means of improving beet varieties, the possible essential nature of sodium as a plant nutrient, and the ease of determining sodium with a flame photometer make the inclusion of this element in the present petiole-sampling technique study highly desirable. The results of these analyses and their statistical evalutaion are given in Table 5. Again, there is a wide range of sodium values in the petioles, 9.00 percent in field 8 Y and only 0.35 percent in field HDY. The sodium means of these fields were as high as 5.60 percent and as low as 1.84 percent.

The confidence limits of the means of all fields are exceptionally narrow and, accordingly, many of the differences between the means are statistically significant even though the biological significance of the values is not known at present. Biologically, there seems to be an inverse relationship between potassium and sodium; for example, the petioles with the highest potassium content (Table 4) have the lowest sodium content (Table 5), and those with the highest sodium content have the lowest potassium content. This inverse relationship is not consistent, however, since the petioles with the third highest potassium content also have the third highest sodium content, showing that there is no simple relationship between potassium and sodium under field conditions.

A review of the components of variance in the field and in the laboratory again points conclusively to the fact that the variations from petiole to petiole in the field are far greater than the variations within the laboratory. Improvements in precision can be made by taking more petioles per sample, but at present more useful information is gained by taking more samples per field instead of taking more petioles per sample.

Discussion

The number of individuals which must be selected at random in order to characterize a population within satisfactory limits of error depends upon the variability of the individuals within the population. In petiole sampling of beet fields, the variability of the petioles is largely composed of three components of variation, of which the variation from beet to beet within the field and between the petioles within the beet are the largest, while the variations between replicated analyses for nitrate, phosphate, potassium and sodium are relatively small. Theoretically, once the overall variability of the petioles from beet to beet within a field has been determined the number of petioles required for a given precision can be calculated readily. Basically, sampling precision increases with the square root of the number of petioles taken per sample.

Table 5.—Sodium in Petioles Expressed in Percentages on a Dry Basis for 17 Sugar Beet Fields as Related to Ranges of Values, Confidence Limits, Components of Variance, Vaiances of Single Determinations, Gains in Precision and Coefficients of Variation.

Field[1]	Range	Mean	Confidence limits at the 5% level[3] — Limits of error — One analysis Petioles per sample 25	One analysis Petioles per sample 50	Two analyses Petioles per sample 25	Two analyses Petioles per sample 50	Gain in precision — Single analysis 50 petioles[4]	Gain in precision — Duplicate analyses 25 petioles[5]	Components of variance (multiplied by 1/100) — Between petioles within field S^2_{LBP}	Analytical — Between dates S^2_t	Analytical — Residual S^2_A	S^2_{LBP}/S^2_T x 100	Variance[2] single analysis x 1/100 — 25 petioles	C.V.[6]
	ppm.	ppm.	ppm.	ppm.	ppm.	ppm.	%	%				%		%
VIII Y	9.00—3.40	5.60	±0.73	±0.56	±0.69	±0.51	30.6	4.8	2.8262	0.0049[7]	0.0187	99.2	0.1366	6.6
V M	7.05—4.00	5.37	±0.38	±0.31	±0.35	±0.27	23.5	8.3	0.6524	0	0.0113	98.3	0.6524	3.6
H Y	7.04—3.05	5.11	±0.42	±0.33	±0.40	±0.30	28.0	5.8	0.8965	0.0014[8]	0.0089	98.9	0.0462	4.2
IX Y	7.60—2.88	4.66	±0.53	±0.40	±0.50	±0.37	30.4	4.6	1.4903	0	0.0127	99.2	0.0723	5.8
I M	7.00—3.00	4.34	±0.42	±0.35	±0.39	±0.30	22.0	9.1	0.7834	0	0.0155	98.1	0.0468	5.0
VII Y	6.10—2.76	4.26	±0.35	±0.27	±0.33	±0.25	27.7	6.1	0.6186	0	0.0072	98.8	0.0319	4.2
B Y	7.50—1.05	3.67	±0.56	±0.45	±0.52	±0.40	25.5	7.3	1.5004	0.0009[8]	0.0210	98.6	0.0819	7.8
XI K	6.72—1.84	3.33	±0.56	±0.40	±0.55	±0.40	38.7	1.1	1.9619	0.0017[8]	0.0016	99.8	0.0818	8.6
XII K	6.80—0.96	3.27	±0.58	±0.44	±0.56	±0.41	32.3	3.8	1.8565	0	0.0125	99.3	0.0868	9.0
XIV K	5.70—1.52	3.12	±0.39	±0.29	±0.38	±0.28	35.9	2.2	0.9193	0	0.0034	99.6	0.0402	6.4
IV M	4.46—1.07	3.06	±0.38	±0.29	±0.36	±0.27	30.7	4.7	0.7544	0.0023[8]	0.0041	99.2	0.0366	6.2
XIII K	5.70—1.12	2.82	±0.49	±0.38	±0.47	±0.35	30.2	4.8	1.2881	0	0.0112	99.1	0.0627	8.9
VI Y	4.72—1.30	2.78	±0.34	±0.27	±0.32	±0.24	28.1	5.9	0.5940	0.0027[8]	0.0040	98.9	0.0305	6.3
II M	3.52—1.20	2.37	±0.26	±0.20	±0.25	±0.18	28.9	5.3	0.3508	0	0.0035	99.0	0.0175	5.6
III M	2.50—1.35	1.96	±0.17	±0.15	±0.15	±0.12	14.8	16.3	0.0869	0.0009[7]	0.0032	95.5	0.0076	4.4
HD Y	4.08—0.35	1.87	±0.31	±0.24	±0.30	±0.22	31.8	4.0	0.5269	0	0.0041	99.2	0.0252	8.5
X Y	2.56—0.72	1.84	±0.15	±0.23	±0.14	±0.21	26.4	6.6	0.4184	0	0.0055	98.7	0.0222	8.1

[1][2][3][4][5][6][7][8] For explanation see Table 2.

Because of this relationship, the greatest increase in precision results from adding the first few petioles to the number of petioles already taken per sample, and thereafter the gain in precision is relatively small unless the error variance is large. Even with the large error variances present in petiole sampling of sugar beet fields, the gain in precision of a 50-petiole sample over a 25-petiole sample is on the average only 28.3 percent for nitrate, 25.1 percent for phosphate, 25.8 percent for potassium and 28.5 percent for sodium (Tables 2, 3, 4 and 5). The gains of a 100-petiole sample over a 50-petiole sample are still less. Thus, when more petioles are to be taken from a field, especially more than 50 petioles, it would be better to take more samples from a field than to take more petioles per sample.

This conclusion contradicts that offered by Brown (1); he stresses the need for greater precision per sample rather than the gaining of information about the variability of the nutrient status of a field. By knowing the nutrient variability of the beets in a field, the fertilizer requirements of the crop can be estimated much more accurately than otherwise. In practice this means that higher critical nutrient levels will be observed in highly variable fields and lower critical levels in uniform fields.

Under some conditions the use of critical nutrient concentrations as a guide to the fertilization of sugar beet fields might be improved by using a rapid procedure to estimate the proportion of the plants in the fields below or above the critical nutrient level.

For example, this can be done easily for nitrogen by using the diphenylamine test for nitrate on petioles of recently matured leaves (7). Whenever 25 percent or more of the field is deficient in nitrogen by this test, i.e. below the critical concentration, nitrogenous fertilizers should be added to the field. This procedure is especially important in very spotty fields such as those observed in Kern county. In field 13 K, as already mentioned, 36 percent of the petiole nitrate values were less than 1,000 ppm., and yet the average value was 4,130 ppm., a figure well above the critical concentration. In another field, 2 S, with an average value of 2,984 ppm., only 12 percent of the samples were less than 1,000 ppm.

Thus, blind adherence to the interpretation of the nutrient status of beet crops based solely on petiole analyses of composite samples without field observations would certainly lead to faulty recommendations in spotty fields. In this particular case field notes included the observation that the pattern of field 13 K was extremely irregular and would require the collection of two distinct samples, one from lush green plants and the other from stunted plants with yellow leaves. The results of the samples taken separately, as shown by an analysis of the individual petioles, would have shown that the samples from the green plants were high in nitrate and the other from the yellow plants much less than 1,000 ppm. of nitrate-nitrogen.

In the case of potassium nutrition field variability, supported by field or laboratory analysis, may be disclosed by the amount of leaf scorch present in the beet field. The amount of necrotic spotting in alfalfa has been found to correlate closely with potassium deficiency in the field (3), and a similar procedure may be found satisfactory for sugar beets whenever areas deficient in potassium are studied intensively. Unfortunately, phosphorus-deficient

plants have no clearly defined deficiency symptoms, except possibly small dark green leaves, which can be used readily to estimate the proportion of phosphorus-deficient plants in a beet field. Fortunately, field and laboratory tests for phosphorus are not difficult to make and can be relied upon for petiole variability studies.

Summary

A detailed study of the technique used in petiole sampling of sugar beet fields for evaluating the nutrient status of beet crops was made on 17 different fields selected over a three-year period in Yolo, Monterey and Kern counties of California.

A statistical analysis of the nitrate, phosphate, potassium and sodium contents of the individual petioles showed that the components of variance between petioles within a beet, between petioles of adjacent beets and between petioles of beets at different locations within a field were large, and furthermore were not related to the order of selecting the petioles within a beet or of beets within a field location. The components of variance for the chemical analyses of the petioles, within and between dates of analysis in the laboratory, were exceedingly small, averaging less than 2.5 percent of the total variance of sampling.

From these observations it seems that the greatest gains in precision are obtained by increasing the number of petioles taken per sample and not by analyzing the same sample more times. Even though the largest gains in precision are made by taking more petioles per sample, the gains are confined mainly to the first few petioles added to the sample. Thus, the average gain for a 50-petiole sample over a 25-petiole sample is only 25 percent, and for more than 50 petioles the gains over a 50-petiole sample are still less. In a further consideration of the sampling problem, particularly in relation to critical nutrient levels, more useful information is obtained by taking more samples per field than by taking more petioles per sample.

The ultimate in sampling procedure is the testing of individual petioles so that the proportion of deficient to non-deficient plants within a field can be estimated accurately. By knowing the proportion of deficient to non-deficient plants within a field, a better evaluation of the nutrient requirements of the crop can be made than by using mean nutrient values alone.

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Effect of Various Nutrient Levels of Soil and Foliar Spray Applications on Sugar Beet Yields

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Experimental data tend to indicate that to secure maximum sugar beet yields a balance of plant nutrients is required. A greenhouse experiment was set up in 1949 to determine this balance and the quantities of each nutrient necessary.

This greenhouse experiment consisted of four levels of nitrogen, phosphorus and potassium in the soil. With these levels occurring in all possible combinations the growth of sugar beet plants indicated the best balance of nutrients. These levels were then applied to a field in an effort to produce maximum yields of beets in the eastern area. The field selected was tiled and had two cuttings of alfalfa plowed under the year previous.

Field Experimental Methods

In work previously reported (1)[2], applications of three rates of phosphorus, potassium and nitrogen were made in an effort to achieve, under field conditions, the levels producing the best growth of sugar beets. The levels were 5, 10 and 15 ppm. for phosphorus and 15, 30 and 45 ppm. for potassium. Soil tests in 1951 indicated that the active phosphorus levels were 6, 12 and 18 ppm. and the potassium levels were 18, 42 and 41 ppm. Nitrogen was applied at 250 pounds and 500 pounds for the higher levels. The plowdown served as the check levels.

All soil tests were by the Spurway active soil testing methods. Spurway green tissue testing methods were used to determine the nitrates, phosphorus and potassium in the green petioles.

These plots were planted to beets again in 1951 and supplemental irrigation was used on one-half of the plots.

Results in 1950 and 1951

The plots which were irrigated twice appear to have outyielded the non-irrigated. Further data will be required to substantiate this.

Soil tests indicate that the sugar beet plant takes up all available nitrogen. Green tissue tests indicate that greater quantities than the plant requires accummulate in the tissues. Yield results show that a heavy application of nitrogen increased yields, but the sucrose percent and gross sugar per acre are lowered as shown in Table 1, all to a statistically significant level of 1 percent. This is true even when available phosphorus and potassium levels are high.

Table 1.—Effect of Heavy Nitrogen Applications on Yields and Sucrose Percent.

	0 lbs. N	250 lbs. N	500 lbs. N
Yield Tons/A	15.5	17.8	17.3
Sucrose %	18.8	15.1	14.3
Gross Sugar	5,837	5,347	4,920

No nitrogen was applied in 1951. The carryover of nitrogen was sufficient to be very evident in top growth. Yield increased significantly and sucrose percent decreased significantly but gross sugar was raised slightly.

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[2] Numbers in parentheses refer to literature cited.

Green tissue tests for potassium indicated no variation in the plant tissue irrespective of the quantity or concentration available in the soil. Tissue tests were equal for soil tests of .5 ppm. to the highest tested level.

The heavier applications of potassium significantly lowered gross sugar as shown in Table 2. The combination of the heavy nitrogen application and the heavy potassium application resulted in a slight increase in yields as indicated in Table 2.

Neither the potassium nor the nitrate concentration of the petioles, as shown by green tissue tests, could account for this.

Table 2.—Effect of Heavy Potassium Applications on Sugar Beet Yields and the Offsetting Effect of a Heavy Potassium Application and a Heavy Nitrogen Application. (500 lbs./A of N.)

	0 lbs. N		500 lbs. N	
	1,785 lbs. KCL	4,725 lbs. KCL	1,785 lbs. KCL	4,725 lbs. KCL
Yield Tons/A	17.2	16.6	17.1	18.1
Sucrose %	16.2	16.0	14.4	14.3
Gross Sugar	5,565	5,223	4,910	5,170

In 1951 soil tests were the same for potassium as in 1950. Yields were increased slightly but percent sucrose was decreased significantly.

Phosphorus levels produced no significant benefit or detriment on beet yields in either year. However, some 1950 data gave indications of lines requiring further investigation. It was found that where no nitrogen was applied the phosphate increased the sucrose percent on 54 plots to 18.9 compared with 18.3 for the check plot. Also, the green tissue tests showed these same plots averaged 10.2 ppm. of phosphorus while the rest of the plots averaged 6.5 and the check plots averaged 5.5. Where both potassium and nitrogen were low, the sucrose percent for 18 plots was 19.2 compared with 18.3 for the check plots. The average phosphorus of the green tissue on these plots was 11.1 ppm. compared with 6.5 ppm. for the other plots and 5.5 ppm. for the check plots.

Therefore, to investigate the role of phosphorus more fully, a set of plots were designed to determine whether phosphorus in the plant tissue could be raised, thereby increasing percent sucrose. Research by other workers has indicated that phosphate in the tissue could be increased by making foliar spray applications of a soluble phosphate.

This experiment was designed with six treatments: 1. check, 2. 60 pounds P_2O_5, 3. 120 pounds P_2O_5, 4. 120 pounds P_2O_5 plus sprayings every week with a saturated superphosphate solution, 5. 120 pounds P_2O_5 plus sprayings every other week with a saturated superphosphate solution, 6. 120 pounds P_2O_5 plus two sprayings with urea. These treatments were used on field check, 50 pounds nitrogen sidedressed and 100 pounds nitrogen sidedressed and a basic application of 60 pounds of K_2O on all plots.

Green tissue tests were made for phosphorus prior to harvesting on four sets of plots: 1. 120 pounds P_2O_5 plus saturated superphosphate sprays every other week, 2. 120 pounds P_2O_5 plus two sprayings of urea, 3. check, 4. 120 pounds P_2O_5, each on 50 pounds of nitrogen, 0 pounds of nitrogen, and 100 pounds of nitrogen. These results shown in Table 3 indicate that the application of phosphate fertilizer increased the phosphorus in the plant but subsequent sprayings with soluble phosphate had no effect.

Table 3.—Parts Per Million of Phosphorus in Green Tissue Under Various Phosphorus Applications.

Quantity applied	ppm. of Phosphorus in Green Tissue
No phosphorus	6.8
120 lbs. P_2O_5	19.4
120 lbs. P_2O_5 plus 5 P_2O_5 sprayings	19.3
120 lbs. P_2O_5 plus 2 urea sprayings	17.5

Table 4 shows that the application of nitrogen lowered the phosphate in the plant tissue in direct relationship to the quantity of nitrogen applied.

Table 4.—The Phosphorus Content of the Green Tissue as Affected by Increasing Nitrogen Applications.

Pounds of Nitrogen	Phosphorus ppm.
0	18.3
50	15.8
100	13.2

This is evident even when urea was applied as a spray as shown by Table 3. The application of urea gave no visible effect on the top growth either in color or in size. Chloroyphyll determinations on the same tissue also indicated that the urea sprays did not affect the green pigments even though the phosphorus in the tissue was decreased.

The determination of the green pigments was made to check on the theory that possibly the concentration of photosynthetic material present as evidenced by the green pigments would correlate with sucrose percent. These tests indicate virtually no correlation of chlorophyll with percent sucrose. A definite correlation of chlorophyll exists with nitrogen. As nitrogen is increased, leaf size is increased and Table 5 shows that the concentration of chlorophyll in that larger leaf is increased.

Table 5.—Relationship of Chlorophyll Concentration to Nitrogen Applications.

Pounds of Nitrogen	Chlorophyll mg/gm
0	.35
50	.55
100	.59

The plant phosphate was not correlated with sucrose percent in this experiment even though high phosphate concentrations were found in some petioles.

It is of interest to note in Table 6 that benefit from 10 weekly phosphate sprays is indicated by the averages of six plots.

Table 6.—Average Yields of Each Treatment.

	Tons/A	% Sucrose	Gross Sugar
Check	13.3	16.5	4,423
60 lbs. P_2O_5	16.3	17.0	5,562
120 lbs. P_2O_5	16.7	17.3	5,725
120 lbs. P_2O_5 + 10 P_2O_5 Sprayings	18.7	17.3	6,462
120 lbs. P_2O_5 + 5 P_2O_5 Sprayings	17.7	16.6	5,845
120 lbs. P_2O_5 + urea sprayings	17.8	17.2	6,068

These averages indicate increases of a ton/A of beets above any other treatment and 400 pounds gross sugar/A and possibly some increase in sucrose percent. Furthermore, there are indications that the weekly phos-

phate spray was of even greater benefit at the 100 pounds application rate of nitrogen.

Summary

Heavy applications of phosphate fertilizer raised the active phosphate level of the soil and maintained it for two years.

Heavy potassium applications increased active soil potassium to a certain level, then no further increase was found.

Heavy nitrogen applications had a marked carry-over to the following year.

Irrigation may have been beneficial in the eastern area.

Yields are increased by heavy nitrogen applications but percent sucrose is lowered. Potassium has similar effects but not so extreme. The combination of heavy potassium and heavy nitrogen applications raised gross sugar slightly.

Phosphorus fertilizer application had no effect except where nitrogen was low. Under low nitrogen conditions phosphorus in the tissue was increased and percent sucrose was increased.

Foliar spray applications of a soluble phosphate every two weeks did not increase phosphate in the tissue.

As nitrogen applications increased, phosphate in the tissue decreased.

No relation was found of chlorophyll concentration and percent sucrose but concentration of chlorophyll was directly related to rates of nitrogen applications.

Weekly foliar sprayings of a soluble phosphate indicates some benefit, especially with the heavier nitrogen application rates.

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Effect of Saline and Alkali Soil on Growth of Sugar Beets

C. H. Wadleigh, A. D. Ayers, and C. A. Bower[1]

The relatively high salt tolerance of sugar beets during the later stages of growth is well known. Although this characteristic is sometimes designated as "alkali" tolerance, in most instances the soil condition under reference is characterized by salinity rather than a high level of exchangeable sodium. It appeared expedient to test the tolerance of sugar beets to salinity and to alkali, per se, on field plots especially prepared to effect uniformity of salinization or alkalization. Eight 10 foot x 10 foot plots were set up according to procedures described by Wadleigh and Fireman (3).[2]

The year previous to the cropping season, four of the plots had been leached with a heavy application of sodium bicarbonate solution so that the resulting exchangeable sodium percentage in the surface foot of soil averaged about 50. The other four plots contained untreated Pachappa fine sandy loam. In each plot four 10-inch beds were prepared so as to be 30 inches apart on center and 5 inches high. On February 18, 1949, two of the beds in each plot were planted to a single row of U. S. 22, and the other two beds were planted with seeds of a selection made by Bion Tolman of the Utah-Idaho Sugar Co. from outstandingly tolerant beets in a field of U. S. 22 seriously afflicted with salinity and located in the Yakima Valley, Washington.

Two plots with normal soil and two with alkali soil were irrigated with Riverside water throughout the season. The former treatment was designated as the "control," and the latter was designated as the "alkali" treatment. The other four plots received irrigation water fortified with NaCl to the extent of 3,000 to 12,000 ppm., the concentration being increased with the advance of the season. Thus, the previously untreated soil receiving saline irrigation water was designated as the "saline" treatment, and the plots which had received the preliminary sodium bicarbonate treatment together with saline irrigation water were designated as the "saline-alkali" treatment.

Nutrient requirements were supplied in the irrigation water. During the forepart of the season, each application of water was fortified with 400 ppm. of metaphosphate and 200 ppm. of KNO_3. Nutrient application was discontinued during July.

Table 1 shows the status of salinity and alkali in the soil samples taken from the centers of the rows at the end of the growing season September 28, 1949. It is to be noted that the sodium bicarbonate treatment resulted in a rather high pH of this soil, and also a rather high exchangeable sodium percentage (ESP). Since the initial ESP averaged about 50, the data for this entity from the alkali plots actually showed that exchangeable sodium

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[2] Numbers in parentheses refer to literature cited.

in the soil had decreased during the course of the season, presumably from the effect of the soluble calcium in the Riverside irrigation water applied. The saline soil showed very high electrical conductivities of the soil extract, relatively low pH values, and very high ESP values. The application of neutral salt, sodium chloride, effected a replacement of calcium from the exchange complex, but the high concentration of salt in the soil solution tended to maintain a nearly neutral reaction. The saline-alkali soil had electrical conductivity and ESP values similar to that of the saline soil, but the pH of the soil extract was much higher.

During the course of the experiment, tensiometers were maintained in the rows and furrows of plots subjected to the various treatments. Water was applied to all plots when the tensiometers in the "control" plots installed at the 8-inch depth showed 400-500 cms. of tension. In the alkali plots, however, the tensiometers were almost continuously off-scale, even

Table 1.—Evaluation of Salinity and Alkali Status of Soil Samples Taken from Centers of Rows on September 28, 1949.

Treatment	Soil stratum	pH of 1:1 extract	EC_e[1]	Exchangeable sodium in soil	
	Inches		Millimhos/cm.	me./100 gms.	Percent[2]
Control	1-9	8.2	0.81	0.05	0.6
	9-18	8.0	.51	.08	1.0
	18-27	7.9	.72	.03	0.4
Alkali	1-9	9.3	3.21	3.01	37.6
	9-18	9.1	1.05	1.90	23.9
	18-27	8.6	.78	.74	9.2
Saline	1-9	7.5	18.0	6.18	77.2
	9-18	7.2	14.4	5.06	63.2
	18-27	7.5	10.5	4.30	53.8
Saline-alkali	1-9	8.6	27.3	7.15	89.4
	9-18	8.4	17.7	4.57	57.1
	18-27	8.1	14.7	3.72	46.5

[1] Electrical conductivity of extract of saturated soil calculated from EC_1 (2).
[2] Based on an exchange capacity of 8 me./100 gms.

when water had been standing in the furrows several days. On irrigating with 1½ inches of water, the water would infiltrate the soil of the control plots in four to five hours' time, but it would stand in the furrows of the alkali plots for several days. It is possible, consequently, that a major fraction of each application of water on the alkali plots was lost through evaporation, and never entered the soil. This effect of high ESP value on the infiltration of water into such soil is typical. Little difficulty was encountered with the infiltration of water on the saline and saline-alkali plots. In these instances the irrigation water contained sufficient electrolyte to counteract the dispersing tendency of the high exchangeable sodium found in the soil of these plots. Although infiltration of water was slower than in the case of the control plots, it would usually disappear from the furrows within 12 hours after a 1½ inch irrigation.

The beets were harvested September 30, 1949. Table 2 presents the average yield of beets from the plots, together with the sucrose percentages of the roots and the mineral content of the foliage. Since there was virtually no difference between the performance of variety U. S. 22 and Tolman's

selection therefrom, observations on the two varieties are averaged in the data of Table 2. The only exception occurred on the saline plots. Under this treatment the Tolman selection produced 15 percent more beets than the ordinary strain of U. S. 22. The difference in yield was significant and suggested that a small advance in salt tolerance was made through selection.

It is evident from Table 2 that the alkali soil containing all the necessary nutrient elements and adequate water as far as application was concerned, resulted in a markedly lower yield. The authors believe that this lower yield was a result of inadequate infiltration of water together with impaired movement down to the roots. Actually, on every hot day during the summer the beets on the alkali plots would be seriously wilted, whereas those on the control plots would be turgid. That is, the difference in yield between the two treatments might well be interpreted as the accrued effect of the difference in soil moisture stress prevailing on the roots under these two conditions during the course of the growing season. The presence of salinity in the irrigation water was associated with relatively low yields in comparison with those observed on the control plots. However, the growth of the beets on these plots was sufficient to correspond to a yield of 30 tons per acre. Since the soil samples from these plots showed EC_e values of 10-20 millimhos/cm. during the major part of the growing season, the high salt tolerance of sugar beets is evident. Most crop plants cannot survive under this level of salinization (2).

Table 2.—Yield, Sucrose Content and Mineral Composition of Beets.

Treatment	Yield[1] lbs./10 foot row	Sucrose content Percent	Cationic content of leaves and petioles			
			Na	K	Ca	Mg
			me. per 100 gms. dry wt.			
Control	69.0	13.4	160	136	44	46
Alkali	51.7	13.9	270	80	36	48
Saline	38.9	14.3	336	81	44	55
Saline-alkali	33.5	12.6	369	65	43	58
L.S.D. (.05)	4.6	1.4				

[1] To convert to T/A, multiply by 0.87.

The sucrose content of all beets at the time of harvest was low, and variation among treatments was not sufficient to warrant comment.

Sugar beet foliage produced on the various treatments showed remarkably little variation in content of calcium and magnesium, but an enormous variation in sodium content and an appreciable variation in potassium. The beets grown under the control treatment actually accumulated 160 me. of sodium per 100 grams of dry tissue. Sodium in the foliage of most species of plants under this treatment would be comparatively low. Inducing exchangeable sodium into the soil almost doubled the sodium content of the leaves, and under the imposed salinization the sodium content of the foliage was more than double that from the control plots. Associated with the variations in sodium content, there tended to be an inverse level of accumulation of potassium; that is, the potassium content of the foliage was at the highest in the control plants and tended to be lower in foliage with the higher sodium content.

In some species of plants, beans for example, variations in the calcium content of the tissue is a good index of the degree to which these plants have been subjected to increasing levels of exchangeable sodium in the growing medium (1). On the basis of the evidence herein presented, calcium content of sugar beet leaves would not be a good index of such soil conditions. On the other hand, even though the sugar beet plant readily accumulates very high levels of sodium in the leaves, it is quite possible that, if the level of accumulation exceeds 200 me. per hundred grams of leaf tissue, the plants may be subjected to adverse levels of salinity and exchangeable sodium in the soil.

Summary

Half of the experimental plots used for this study were set up on the normal soil prevailing on the grounds of the Salinity Laboratory. The remaining plots had been leached the previous year with a heavy application of sodium bicarbonate solution, so that the exchangeable sodium percentage of the upper two feet of soil averaged about 50. Half of the plots on each of the two soil conditions were then irrigated with normal irrigation water, and the other half of the plots received irrigation water which had been fortified with NaCl to the extent of 3,000-12,000 ppm., the concentration being increased with the advance of the season.

Serious difficulty was encountered in obtaining water penetration on the alkali plots. Following irrigation, water would stand in the furrows for days at a time; consequently, the plants in these plots would wilt seriously on days conducive to a high rate of transpiration. In view of the frequency with which beet plants in the alkali plots showed moisture stress, the yields were surprisingly good.

Even though the imposed level of salinization was high and effected a 50 percent reduction in yield, the beets on these plots made surprisingly good growth.

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Influence of Sodium Bicarbonate on Mineral Composition of Red Garden Beets

C. H. WADLEIGH AND J. W. BROWN[1]

The bicarbonate ion is one of the principal components in many of the irrigation waters applied on sugar beet fields in the western states. Wadleigh and Brown (2)[2] have reviewed the effect of an accumulation of sodium bicarbonate in the soil solution upon plants, and presented experimental data as to the effect of the bicarbonate ion in the substrate on chemical composition and growth response of bean plants. Since beans are remarkable in their capacity to exclude the sodium ion, it appeared expedient to study the effect of sodium bicarbonate on a species which was outstanding in its capacity to accumulate the sodium ion. Accordingly, beets were selected as the experimental plant, and since red garden beets are more convenient to work with in greenhouse experiments, they were used as the test plants. With proper qualifications, the results obtained from red garden beets are applicable to sugar beets.

Experimental Procedure

Selected seedlings of the Crosby Egyptian variety of red garden beets were grown in automatically irrigated sand culture equipment (1) in which the control nutrient solution was composed as shown in Table 1. Seeds were planted February 27, 1948, and treatments were initiated April 9, 1948, when the plants were 4 to 5 inches high. Each treatment was replicated three times and consisted of the addition of 0, 8, 16, and 32 m.e./liter $NaHCO_3$ to the control nutrient solution.

Table 1.—Composition of Control Nutrient Solution.

$Ca(NO_3)_2$	5.0 m.e./liter	K_2SO_4	2.0 m.e./liter
$MgSO_4$	3.0 m.e./liter	$MnSO_4$	0.5 ppm
KH_2PO_4	0.5 m.e./liter	H_3BO_3	0.5 ppm
K_2HPO_4	0.5 m.e./liter	FeCitrate	0.5 ppm
KNO_3	2.0 m.e./liter		

The pH of the control was adjusted daily to 8.0 with NaOH, and the solutions were changed completely at least once a week. Solutions with added $NaHCO_3$ had an initial pH of about 8.0. When the pH of these solutions reached 8.3 they were replaced with freshly prepared solution. Thus, pH was essentially eliminated as a variant in this experiment.

The plants were harvested on April 30. After determining fresh weights of tops and roots, samples of tissue were dried in a forced-draft oven. The methods of analysis followed were those previously reported (2).

Observations

The growth response of the beets on the various experimental treatments is shown in Table 2. All plants made excellent growth. There was no difference in response between plants receiving 0 and 8 m.e./liter of

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[2] Numbers in parentheses refer to literature cited.

added $NaHCO_3$; but the higher levels of added $NaHCO_3$ were associated with appreciably smaller tops; and the highest level of treatment was characterized by definitely the smallest roots. Accordingly, there was a tendency for the top-root ratio to increase with increasing concentration of bicarbonate in the growing medium. Even though beets were remarkably tolerant of the bicarbonate ion, the data suggested that any adverse effect is more serious to the development of the tap, or storage, roots than to vegetative growth of the tops.

The cationic content of leaf blades and storage roots of the experimental plants is shown in Table 3. The accumulation of sodium in the blades with increasing levels of $NaHCO_3$ in the growing medium is the

Table 2.—Growth Response of Beets Under the Four Treatments.

$NaHCO_3$ in substrate	Green weight per plant (Ave. of nine plants)			Top/root ratio	Dry weight per plant
	Tops	Roots	Total		
m.e./liter	gms.	gms.	gms.		gms.
0	105	111	216	0.95	17.8
8	110	107	217	1.03	17.8
16	82	76	158	1.08	13.5
32	81	48	129	1.69	11.3

outstanding feature of this table. It is to be noted that the level of sodium accumlation in these red beet leaves compares closely with the level of sodium accumulation found in the foliage of sugar beets on saline or alkaline soil (3). Although the level of accumulation of sodium in storage roots is relatively small compared with that which may take place in the leaves, it is evident that under the experimental conditions here imposed there was found to be a four-fold increase in the content of sodium in the storage roots with increasing level of $NaHCO_3$. Such a trend in sodium accumulation in sugar beets might have an adverse effect on quality. As variations in treatment brought about higher accumulations of sodium in the tissues, there were observed correspondingly lower levels of potassium

Table 3.—Cationic Content of Leaf Blades and Storage Roots.

$NaHCO_3$ in substrate	Mineral content of tissues									
	Na		K		Ca		Mg		Total cations	
	Leaf blades	Storage root	Leaf blades	Storage root	Leaf blades	Storage root	Leaf blades	Storage root	Leaf blades	Storage root
m.e./liter	m.e. per 100 gms. dry tissue									
0	51	17	162	159	35	7	225	24	473	207
8	178	49	100	129	27	4	189	22	494	204
16	238	70	70	86	29	5	175	20	512	181
32	312	77	56	76	23	3	179	19	570	175

accumulation, even though the supply of potassium to the plants was a constant. Beet plants are characteristically very low in content of calcium, and this is evident in the data of Table 3. Increasing levels of sodium bicarbonate in the growing medium were found to be inhibitive of calcium accumulation.

Beets are remarkable for the high level of magnesium accumulation which may be found in the tissues. Here again, however, as in the case with the sodium ion, the level of the accumulation in the leaves is much higher than in the roots.

Total accumulation of cations in the leaf blades tends to increase with increasing concentration of $NaHCO_3$ in the growing medium, but a reverse trend was observed in the storage roots.

It is recognized that accumulation of cations in plant tissues is in large degree electrovalently balanced by accumulation of organic anions. It may be noted from data presented in Table 4 that total organic acid accumulation in the two tissues studied tended to approach that observed for total cation content of the tissues, with the exception that total organic acids tended to increase with level of treatment in both tissues. It is evident that in the blades oxalic acid represents the preponderant proportion of the total organic acids assayed, and that citric and malic acids contribute relatively insignificantly to the total. In the roots, however, oxalic acid represents less than one-third of the total organic acids and the preponderant proportion of the organic acids is represented by some constituent not assayed.

Table 4.—Organic Acid Content of Leaf Blades and Roots.

	Total organic acids		Oxalic acid		Citric acid		Malic acid	
$NaHCO_3$ in substrate	Leaf blades	Storage root	Leaf blades	Storage root	Leaf blades	Storage root	Leaf blades	Storage root
m.e./liter	m.e. per 100 gms. of dry tissue							
0	374	107	354	32	7	2	7	4
8	386	104	346	27	7	7	6	5
16	403	122	344	33	12	9	4	11
32	527	129	444	30	17	8	12	11

The data recorded suggest that beets grown under alkaline conditions (see 3) may contain rather high accumulations of sodium oxalate in the foliage, since the resulting accumulation of sodium in the tissues is largely counterbalanced electrovalently by oxalate.

Summary

Red beets were grown in sand cultures supplied with nutrient solutions adjusted to pH 8 with the added level of sodium bicarbonate being the only variant in order to test the response of this species to the bicarbonate ion. Four different nutrient solutions were employed: (a) No added sodium bicarbonate; (b) addition of 8 m.e./liter $NaHCO_3$; (c) addition of 16 m.e./liter, and (d) 32 m.e./liter. The growth of beets was less influenced by the presence of the bicarbonate ion in the substrate than has been found for numerous other species studied; but this ion had a definitely adverse effect at the higher levels of concentration used.

Since beets are outstanding as accumulators of sodium, it is to be noted that even with a moderate level of sodium in the substrate (32 m.e./liter) the beets so produced contained 7.8 percent of sodium in the dry matter of the blades, but only 0.8 percent sodium in the dry matter of the large

roots. Sodium accumulation tended to be accompanied by oxalate accumulation.

With respect to both content of cations and accumulation of organic acids, the large roots were found to be less sensitive than the leaves to variations in sodium bicarbonate concentration in the growing medium.

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Effect of Irrigation Practices Upon the Nitrogen Metabolism of Sugar Beets

ALBERT C. WALKER, LUCILE R. HAC[1] [2]

Satisfactory explanations for the wide variations in yield of sugar beets are frequently not possible. This is especially true of yields ranging from 20 to 35 tons per acre. Sugar beets showing no signs of disease, with full stands, proper cultivation, grown on productive soils, given optimum fertilizer and grown under similar climatic conditions, produce harvested yields which vary from 10 to 15 tons per acre and 3 to 4 percentage units of sucrose. Comparable data does not exist for glutamic acid, but in a small series of tests where glutamic acid measurements have been made values from 0.05 to 0.5 percent are reasonably common.

Insufficient attention has been given to the influence of soil moisture conditions, and method of irrigation on yield and quality of sugar beets. Marcum, et. al. (8)[3] obtained soil moisture differences but could not demonstrate yield differences. Nuckols (11) obtained significant yield differences for various soil moisture conditions one year, but no differences the second year. Doneen (2) concluded that sugar beets were not responsive to soil moisture conditions. Haddock and Kelley (5) and Haddock (6) obtained marked differences in yield among four soil moisture conditions studied and Archibald and Haddock (1) showed that method of irrigation as well as soil moisture condition markedly influenced yield and quality of sugar beets.

It would be of value to know the cause of these conflicting results. Are they due to the balancing of growth factors which operate in opposing directions, or are the effects of soil moisture conditions so small that differences are difficult to measure, or do climatic factors overshadow the effects of soil moisture conditions?

In the present study a more direct and complete measure of nitrogen response under varying soil moisture conditions has been made possible by the inclusion of data on the glutamic acid content of the beet. The utilization of yield, sucrose and glutamic acid data for the calculation of discriminant functions which maximize differences between treatments permits a numerical evaluation of environmental effects not otherwise possible.

Discriminant functions suitable for measurement of the difference between two classes have been applied to a wide variety of problems among which are the classification of *Iris* spp. by R. A. Fisher (4), identification of races of *Drosophila pseudo-obscura* by Mather and Dobzhansky (9) and the selection of breeding stock in wheat by H. Fairfield Smith (12). Mather (10) gives an excellent treatment of their derivation and use.

Experimental Procedure

The data presented in this paper were obtained from an experiment on irrigation and soil management of crops in rotation at Logan, Utah.[4]

[1] The authors are indebted to Dr. J. L. Haddock, Division of Soil Management and Irrigation Agriculture, USDA in cooperation with the Utah Agricultural Experiment Station who supplied us with the samples for glutamic acid determinations. The basic data on yield of sugar beets, sucrose percentage of beets, fertilizer and irrigation data is his. We wish to express our appreciation to Dr. Haddock for his cooperation and interest in this study and for his assistance in the preparation of the manuscript.

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[3] Numbers in parentheses refer to literature cited.

[4] Part of a study under Research and Marketing Act of 1946 with 11 Western States, Alaska and Hawaii cooperating with U. S. Department of Agriculture (Project W-9).

The complete report of the 1950 results is to be found elsewhere (7). The portion referred to in this paper has to do with the effect of two types of irrigation, four soil moisture conditions and two levels of nitrogen fertilizer on the yield, sucrose percentage, glutamic acid content and nitrogen status of sugar beets.

Each of the four replications was divided into eight sub-blocks for purposes of testing the effects of the two types of irrigation (sprinkler vs. furrow) and four soil moisture conditions described in Table 1. Superimposed upon each irrigation soil moisture block were eight fertilizer plots described in Table 2.

Table 1.—Irrigation and Soil Moisture Description and Symbols.

Irrigation Symbols[1]	Soil Moisture Level and Symbol	Description of Treatment
		Irrigation when soil moisture content in root zone is:
1F and 1S	High tension plots low moisture (W_1)	Near permanent wilting or about 8 atmospheres tension as shown by gypsum blocks. (Total of five S or four F irrigations)
2F and 2S	Medium-high tension medium-low moisture (W_2)	At ⅓ available soil moisture remaining or about 4 atmospheres tension as shown by gypsum blocks. (Total of six S or six F irrigations)
3F and 3S	Medium-low tension medium-high moisture (W_3)	At ⅔ available soil moisture remaining or about 0.6 atmospheres tension as shown by tensiometers. (Total of eleven S or nine F irrigations)
4F and 4S	Low tension high-moisture (W_4)	Near field capacity or 0.2 atmospheres tension as shown by tensiometers. (Total of fourteen S or twenty-two F irrigations)

[1]F = Furrow irrigation; S = Sprinkler irrigation by Perf-O-Rain pipe.

All information on fertilizer treatments except nitrogen was averaged out.[5] Average data for sucrose, weight and glutamic acid (geometric mean) are shown in Table 3. The discussion has been divided into:

1. The results derived from information within sub-blocks, viz., the nitrogen response and its changes with irrigation practice.
2. The results derived from information between sub-blocks, viz., effects of irrigation connected with nitrogen changes, and those independent of nitrogen.

Effects of Nitrogen

The yield of beets and sugar as affected by nitrogen fertilizer showed a significant variation from block to block, hence 21 D.F. are available for measurements of the confidence limits for responses to nitrogen as shown in Table 3. The yield of beets and the increase in glutamic acid content of beets in response to nitrogen fertilization increase with increasing supply of water. On the other hand, sucrose is decreased when nitrogen is added to the soil. This depression in sucrose as influenced by nitrogen fertilization is lessened with increasing water supply.

The data in Table 3 may be used to contrast the influence of nitrogen on yield of beets, glutamic acid content and sucrose percentage under furrow vs. sprinkler irrigation. It will be observed that, as soil moisture increases under both furrow and sprinkler irrigation, nitrogen fertilizer increasingly

[5] Pulp samples for glutamic acid determinations were composited from four fertilizer plots on each irrigation—soil moisture plot. Thus two 10-beet samples were obtained from each of the two plots receiving no treatment and composited with a similar sample from each of two plots receiving phosphorus only. This no-nitrogen plot sample was a composite of 80 beets. The pulp sample for plots receiving 80 pounds of nitrogen was also a composite of 80 beets.

stimulates yields of beets and glutamic acid content of beets. This effect is more pronounced under furrow than under sprinkler irrigation. Sucrose percentage is conversely affected by soil moisture condition as well as by method of irrigation. Whereas it appears as though these differences are closely related to the greater quantity of water supplied to the soil by furrow than by sprinkler irrigation, some other explanation must be found to satisfy the differences between soil moisture level 1 and 2. Sprinkler irrigation required approximately the same quantities of water as furrow at these levels. This is not to say that some deep percolation and loss of soil nitrogen did not occur under furrow irrigation at soil moisture level 2. The data on glutamic acid and sucrose percentage indicate that the nitrogen status was better under sprinkler than furrow irrigation and hence that some nitrogen may have been lost to sugar beets, or at least was rendered less available under furrow irrigation.

Table 2.—Fertilizer Symbols and Treatments.

Fertilizer Symbol	Number of plots	Fertilizer Treatments[1] (acre basis)
O	2	No treatment.
P	2	100 pounds of P_2O_5 per acre as treble superphosphate.
N	2	80 pounds of nitrogen per acre as ammonium sulfate.
NP	2	100 pounds of P_2O_5; 80 pounds of nitrogen.

[1] Drilled on soil surface April 14, sugar beets planted May 1, 1950.

Table 3.—Effect of Varying Soil Moisture Conditions upon Nitrogen Response in Sugar Beets.

	Tons Beets per Acre					
Soil	Furrow			Sprinkler		
Moisture	N = 0	N = 80	Diff.[1]	N = 0	N = 80	Diff.[1]
W1	13.9	14.6	0.7	15.7	14.7	—1.1
W2	17.8	19.3	1.5	16.4	17.5	1.1
W3	16.0	19.8	3.8	21.1	19.9	—1.1
W4	14.5	20.8	6.3	18.1	20.1	2.0
LSD (5%) of Nitrogen Difference 2.6						
	% Sucrose					
Soil	Furrow			Sprinkler		
Moisture	N = 0	N = 80	Diff.[1]	N = 0	N = 80	Diff.[1]
W1	16.7	15.6	1.1	16.5	15.4	1.1
W2	17.2	16.9	0.3	16.7	16.1	0.6
W3	17.6	17.4	0.1	16.9	16.2	0.7
W4	17.3	17.3	0	17.0	16.7	0.3
LSD (5%) of Nitrogen Difference 0.5						
	% Glutamic Acid					
Soil	Furrow			Sprinkler		
Moisture	N = 0	N = 80	Diff.[1]	N = 0	N = 80	Diff.[1]
W1	.12	.24	91%	.18	.27	44%
W2	.08	.19	148%	.15	.24	59%
W3	.06	.16	179%	.14	.26	80%
W4	.04	.16	280%	.07	.19	166%
LSD (5%) of Nitrogen Difference 33%						
	Nitrogen Status					
Soil	Furrow			Sprinkler		
Moisture	N = 0	N = 80	Diff.[1]	N = 0	N = 80	Diff.[1]
W1	359	451	92	394	465	72
W2	293	375	82	370	429	59
W3	258	339	81	349	424	76
W4	246	342	96	295	384	89
LSD (5%) of Nitrogen Difference 23						

[1] Nitrogen Response.

Arrangement: Randomized split plot design, four replications. Harvest area per sample: four plots of three 24-foot rows. Sample size: 80 beets; 20 beets each from four plots. Planted May 1, 1950. Harvested October 21, 1950.

In order to examine the relationships among the various factors in Table 3 consider the following data from a study of sugar type and yield type of beets.

	% Sucrose	% Glutamic Acid	Tons Per Acre
Yield type	16.1	.158	17.4
Sugar type	17.1	.205	13.4

Here glutamic acid rises with sucrose, yield decreases with increasing sucrose, and with increasing glutamic acid. This will be referred to as a $+ - -$ correlation pattern (r_{SG}, r_{SW}, r_{GW}). Had the glutamic acid of the first crop been 0.40 instead of 0.15 the correlation pattern would be $- - +$ and it might be asserted with considerable confidence that the first crop had been able to obtain more nitrogen than the second (14).

The analysis of variance shown in Table 4 compares the average size of the various nitrogen responses to their overall error. Inclusion of the significant interactions in the error reduces the effect of nitrogen on weight. Nitrogen has its usual $- - +$ correlation pattern, but its error has a strongly marked $+ + +$ pattern. When highly significant correlations such as this occur, it is possible to take advantage of them by calculating a discriminant function (10) which is a linear compound of the three measured values percent sucrose (S), 3 + log percent glutamic acid (G), and ton beets per acre (W) which gives the greatest possible significance to the effect of nitrogen. If one constructs a three dimensional graph of the results, the discriminant shows the direction of measurement in space giving the greatest significance. The coefficients b^S, b^G, and b^W of S, G, and W respectively in the discriminant function are calculated by a solution of the equations

$$b^S A_{SS} + b^G A_{SG} + b^W A_{SW} = a_{SS}$$

$$b^S A_{SG} + b^G A_{GG} + b^W A_{GW} = a_{GG}$$

$$b^S A_{SW} + b^G A_{GW} + b^W A_{GW} = a_{WW}$$

where A_{SS}, A_{SG}, etc., are the mean squares for error of S, the mean cross product for error of SG, etc. (or any set of values proportional to such mean squares and cross products), and a_{SS}, a_{GG}, and a_{WW} the corresponding root mean squares (on 1 D.F.) for nitrogen (or any set of proportional values). This gives a discriminant function

$$Y' = b^S S + b^G G + b^W W$$

as the quantity maximizing the significance of the nitrogen difference. Ordinarily it is convenient to choose one of the measurements as a basis for comparison by giving it an arbitrary coefficient— $\pm$ 1 or $\pm$ 10. In the present case

$$Y = b^G Y'/10 = (10\, b^S/b^G) S + 10G + (10 b^W/b^G) W.$$

The analysis of variance in Table 4 gives

$$Y = -1.92S + 10G - .115W. \qquad \text{Eq. 1}$$

It is convenient to choose the coefficient of G arbitrarily as 10. In order to avoid negative values of Y and to give a standard form comparable between experiments, it is also convenient to make the equation formally equivalent to 10 (3 + log % GA) at 15 percent sugar and 25 tons per acre by adding the constant 1.92 (15) + .115 (25) = 31.68:

$$Y = -1.92S + 10G - .115W + 31.68 \qquad \text{Eq. 2}$$

The quantity Y is referred to as the *nitrogen status*: it is the most sensitive available measure of differences in the effect of applied nitrogen. Although generally of the form given, the coefficient of S has been found to vary in other experiments[6] from +0.7 to —3.1 and that of W from +0.6 to —0.4, representing the change from extremely low nitrogen (so low that added nitrogen tends to increase sugar) to extremely high nitrogen (so high that added nitrogen actively depresses yield). In variety trials at a single level of nitrogen, this discriminant has frequently been found by maximizing block or environmental differences. Theoretical implications of the nitrogen status and of other discriminants calculated have been discussed elsewhere (13). Changes in the direction of Y measured in this experiment would produce — + — correlation patterns characteristic of changes at a higher nitrogen level than the — — +. Under the extreme conditions above, nitrogen produces a + + + pattern. The increase in accuracy afforded by the use of this discriminant can be judged from the increase in F values shown in Table 4. A further measure of the increase in sensitivity and uniformity of response is given by the assumption, for comparative purposes, that each irrigation method gave equally spaced water levels. This permits the calculations of the following F values based on 26 degrees of freedom:

	DF	S	G	W	Y
Nitrogen	1	45.1	297.4	13.3	549.8
Interaction with Method	1	4.2	17.4	9.9	n.s.
Interaction with Water Levels	1	16.9	25.7	10.3	8.3
Interaction with Blocks	1	10.8	n.s.	3.3	n.s.

Interactions are removed or greatly reduced, and the nitrogen status discriminant gives nearly twice as much information about nitrogen differences as the best single measurement, glutamic acid.

Accordingly, it seems appropriate to use the nitrogen status as a biological assay of the relative amounts of nitrogen available to the sugar beet. The average change in Y with 80 lbs. N was 4.24; the equation may be calibrated in terms of lb. N/acre (applied before planting) by multiplying eq. 2 by the factor 80/4.24:

$$\text{Nitrogen Status} = -36S + 190G - 2.1W + 594 \qquad \text{Eq. 3}$$

Nitrogen status as estimated by eq. 3 gives a measure of the nitrogen applied of 80 ± 8 lbs. Average values of the nitrogen status calculated for each treatment are given in Table 3. The general level of the nitrogen status is arbitrary, only the differences have significance.

Effect of Irrigation on Nitrogen Status

Average values over both nitrogen levels and their appropriate confidence intervals (5 percent points on 21 D.F.) are given in Table 5. It is of interest that the results on furrow irrigation for percent sucrose, yield of beets and gross yield of sugar reproduce those of Doneen (3) quite pre-

[6] Unpublished data International Minerals & Chemical Corporation.

cisely. Sprinkler irrigation gave an increasing yield up to a higher water level (best at 24.5) than did furrow irrigation (best at 17.8 in.). The optimum crop tends to be better under sprinkler irrigation, but not significantly so.

The data on glutamic acid show a strong decline with increasing water. This was also confirmed by a corresponding effect on many of the other nitrogenous components of the beet.[7] This result is diametrically opposed to that of Doneen (2) who found no difference in nitrogen content over a similar range of irrigation treatments. This is evidently attributable to a wide difference in leaching or other nitrogen loss in the two soils.

Table 4.

		Mean Squares and Mean Cross Products						
	DF	S^2	G^2	W^2	SG	SW	GW	Y^2
Error	31	0.36742	.030258	11.924	+.070762	1.5162	.48160	497.99
N	1	8.8726	3.7538	87.450	—5.7711	—27.855	18.118	207676

F Values			
S	G	W	Y
24.15[b]	124.06[b]	7.33[a]	417.03[b]

Correlation Coefficients		
SG	SW	GW
+.67[b]	+.72[b]	+.80[b]

[a] It is significant at 5% point.
[b] It is significant at 0.1% point.

Application of the nitrogen status discriminant to the sub-block data indicates still more significant differences. Sprinkler irrigation left beets with a highly significantly greater nitrogen status: 56 $\pm$ 24 lb., on the average. At the optimum water level the difference must be even greater —at least 70 lb. On the average sprinkler irrigation caused a reduction in nitrogen status of 3.9 $\pm$ 2.1 lb. N. per inch water, while the average reduction for the lower three furrow irrigations was 7.1 $\pm$ 3.6 lb. N per inch water applied. The increase from 28 to 64 inches of water in the highest soil moisture level of furrow irrigation caused no further reduction in the nitrogen status.

Irrigation Effects Independent of Nitrogen

In an attempt to discover what, if any, significant effects might be shown by the irrigation level, other than that of reduction of nitrogen status, the nitrogen status equation 1 was expressed in units of the standard deviation (σ), the square root of mean square for error Table 4 corresponding to the 31 D.F. for error from which equation 1 was calculated. This gives:

$$Y = -1.16S' + 1.74G' - 0.40W' \qquad \text{Eq. 4}$$

where $S' = S/\sigma_S = S/\sqrt{0.36742}$ and $G' = G/\sigma_G$ and $W' = W/\sigma_W$.

The coefficients of this equation express the relative contributions of the three measured variables to information about nitrogen status. Secondary discriminant functions, which maximized the significance of effects *perpendicular* to equation 4, were calculated (13). Six such discriminants maximizing the differences between adjacent water levels for each irrigation were calculated. The only discriminant even approaching significance was that between the second and third water levels of sprinkler irrigation, but the one between the first and second level indicated the same direction of measurement. Therefore, the biggest difference between water levels perpendicular

[7] Unpublished data Haddock and Linton.

to the nitrogen status discriminant should be given by maximizing the difference between the first and third levels of sprinkler irrigation. Expressing the results in terms formally equivalent to tons of beets at 15 percent sucrose and 0.15 percent glutamic acid, equation 5 was obtained:

$$Z = 3.5S + 13G + W - 80.8 \qquad \text{Eq. 5}$$

This discriminant, in this case showing the major effect of water level **not** associated with changes in nitrogen status, has been previously identified (13) with various other genetic and environmental changes and has been called the *growth potential.* Being an increasing function of both sucrose

Table 5.—Effects of Furrow and Sprinkler Irrigations after Averaging Values at Both Nitrogen Levels.

Soil Moisture	Inches Water Applied		Tons Beets		% Sucrose		Tons Sugar	
	F	S	F	S	F	S	F	S
W1	15.6	17.0	14.29	15.19	16.11	15.98	2.30	2.43
W2	17.8	18.9	18.56	16.94	17.08	16.38	3.17	2.77
W3	28.0	24.5	17.89	20.50	17.49	16.53	3.13	3.39
W4	64.3	37.6	17.66	19.09	17.28	16.84	3.05	3.21
LSD (5%)			2.9		0.71			

Soil Moisture	% GA		Nitrogen Status		Growth Potential		Storage Potential	
	F	S	F	S	F	S	F	S
W1	.17	.22	405	429	19	21	17.9	17.8
W2	.12	.19	354	400	25	23	17.9	17.8
W3	.09	.19	298	386	24	27	18.3	17.4
W4	.08	.12	294	339	22	24	18.0	17.6
LSD (5%)	45%		47		5		0.6	

and weight, it is closely related to the measure of gross sugar per acre, and appears to be the best available measure of total vigor, or energy production, of the beet crop. In the present experiment, with beets at an adequate nitrogen level, the chief role of glutamic acid in the equation is to correct for the large changes which variations in nitrogen can make in sucrose content without resulting in weight changes. In experiments at deficient nitrogen levels, the coefficient of G becomes negative.

Values of the growth potential are shown in Table 5. Although the results seem quite similar to the tonnage data, the measurement is actually made at a 41° angle with the W axis. The effect of water is to first raise and then lower the growth potential—tending to raise and then lower weight, sucrose and glutamic acid in the same direction, if nitrogen changes are avoided. Growth potential changes produce a + + + correlation pattern at this nitrogen level and a − + − pattern at lower nitrogen levels.

Residual Variation

The function measuring variation perpendicular to both nitrogen status and growth potential is:

$$X = S + 1.6G - 0.16W + 0.5 \qquad \text{Eq. 6}$$

expressed in terms formally equivalent to percent sucrose at 25 tons per acre and 0.15 percent glutamic acid. This function has been previously found by maximizing differences between sugar beet varieties and is called the *storage potential.* In the present experiment it is a major component of the environmental differences. If the assumption of equally spaced water

levels is again made for comparative purposes, the following F values based on 25 D.F. between sub-blocks are obtained:

	DF	S	G	W	X	Y	Z
Irrigation Method	1	10.8	25.8	n.s.	7.3	23.6	n.s.
Water Level (Linear)	1	19.0	29.5	14.8	n.s.	40.1	5.0
Curvature in Water Effect	1	3.5	n.s.	7.1	n.s.	n.s.	7.5
Blocks	3	8.9	12.0	n.s.	14.8	33.5	n.s.

It can be seen that the bulk of information of the experiment is traceable to one cause: variations in nitrogen. All remaining variation caused by water level is accounted for on the basis of an independent factor, the growth potential, which appears to measure the rise and fall of energy output of the beet. All remaining variation of irrigation method and environment, on the other hand, is caused by a third independent factor, the storage potential, which appears to measure the distribution of energy between growth and storage. Changes in the direction of the storage potential equation tend to produce a $+ - -$ correlation pattern.

It is interesting that the four possible correlation patterns referred to in this discussion are all represented. Naturally the error variation of most experiments is a composite of many sources of variation, so that frequently one or more of the three correlations becomes non-significant. When a single source of variation predominates, one of the following patterns appears:

Pattern			Caused by Changes in	Condition
r_{SG}	r_{SW}	r_{GW}		
$-$	$-$	$+$	Nitrogen Status	Low Nitrogen
$+$	$-$	$-$	Storage Potential	Any Nitrogen
$-$	$+$	$-$	Nitrogen Status	High Nitrogen
			Growth Potential	Low Nitrogen
$+$	$+$	$+$	Growth Potential	High Nitrogen
			Nitrogen Status	Extremely Low or High Nitrogen

Further work may permit further differentiation of the latter two patterns on the basis of the size of regression coefficients involved.

Summary

1. A method for measuring changes in nitrogen status has been presented.

2. Application of this method to an irrigation experiment showed that large losses of available nitrogen can be caused by irrigation even under fairly dry moisture conditions.

3. Losses in nitrogen are greatly reduced by the use of sprinkler irrigation. Savings of 56 lbs. N per acre or more are effected.

4. Residual effects of water are measured by and explained on the basis of growth potential. Increasing growth potential tends to give a concurrent increase of yield, sucrose content and glutamic acid content.

5. The concepts of nitrogen status, growth potential, and storage potential are used to explain the occurrence of four correlation patterns of sugar beets.

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Variability of Open-pollinated, Inbred and Hybrid Sugar Beet Varieties in Greenhouse Experiments[1]

ALBERT ULRICH[2]

One of the characteristic features of experiments with sugar beets is the large variation of the individual plants within a given beet variety. This variability is not serious for measurements based upon 20 or more plants, but where the space available for experimentation restricts the number of plants to less than 20, any reduction in variability becomes extremely important, not only to conserve space but to decrease the differences required for significance between treatment means. Of the two main avenues open to a reduction in experimental error, namely, improvement in technique and in the utilization of varieties of greater genetic uniformity, only the latter approach, in which inbred and hybrid varieties are contrasted with open-pollinated varieties, seemed desirable.

Such a uniformity trial may be conducted readily in an uncontrolled climate; however, to broaden the basis for judging the variability of each variety it is desirable to grow the varieties in a series of climates, preferably controlled climates, such as those now available in the Earhart Plant Research Laboratory at Pasadena, California (4).[3] By growing each variety in a series of climates and by using a balanced statistical design for conducting the experiment approximately six times as much information was obtained with the same number of pots as proposed originally for comparing the uniformity and performance of each variety in a single climate. The results for six climates with eight varieties are reported in this paper.

Procedure

The eight sugar beet varieties used in this experiment are listed according to type and source of material in Table 1. Of these varieties two are open-pollinated commercial varieties, four are inbreds and two are hybrids. The six climates used in growing the plants are given in Table 2.

The sugar beet seeds of each variety were planted in expanded vermiculite at a depth of ¾ inch at the rate of 10 seed balls per pot on February 2, 1951. Twenty-four pots were used for each variety, or a total of 192 pots for the entire experiment. After the seeds were planted, the pots were watered daily with Hoagland's complete culture solution (solution 1) (2) in order to keep the plants well supplied with water and nutrients. The culture solution was always added in excess, and this excess was permitted to drain out through holes in the bottom of the pots.

During the initial growth period, February 2 to March 13, the pots were kept in the greenhouse in sunlight for natural day lengths. The air temperature during this period was 23° C. from 8:00 a. m. to 4:00 p. m., and 17° C. from 4:00 p. m. to 8:00 a. m. As the plants developed, they were thinned to a single plant per seed ball at the early two-leaf stage, to four

[1] The present investigation with sugar beet plants was conducted in the Earhart Plant Research Laboratory, California Institute of Technology, Pasadena, California, by the University of California College of Agriculture in cooperation with the California Institute of Technology and the Beet Sugar Development Foundation. The author is indebted to H. L. Kohls, Michigan State College, Lansing, Michigan; to F. V. Owen, Division of Sugar Plant Investigations, Bureau of Plant Industry, U. S. D. A., and to Henk Rietberg, Instituut voor Rationele Suikerproductie, Bergen op Zoom, Holland, for supplying seed from their breeding stocks for these experiments.

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[3] Numbers in parentheses refer to literature cited.

Table 1.—Sugar Beet Varieties.

Variety	Description	Source
U. S. 22/3 (Elite stock)	Open-pollinated	Utah-Idaho Sugar Company Salt Lake City, Utah
G. W. 304	Open-pollinated	Great Western Sugar Company Denver, Colorado
Female parent of H. 148 (Ac. 35 410603E_3)	Inbred	H. L. Kohls, Michigan State College Lansing, Michigan (5)
Male parent of H. 148 (Ac. 32 57305)	Inbred	H. L. Kohls, Michigan State College Lansing, Michigan (5)
H. 148 (G. H. 1950)	Hybrid	H. L. Kohls, Michigan State College Lansing, Michigan (5)
CT9 (S. L. 69)	Inbred	F. V. Owen Division of Sugar Plant Investigations Bureau of Plant Industry United States Department of Agriculture Salt Lake City, Utah (6)
U. S. 35 MS x CT9 (S. L. 6105)	Hybrid	F. V. Owen Division of Sugar Plant Investigations Bureau of Plant Industry United States Department of Agriculture Salt Lake City, Utah (7)
492	Inbred	Henk Rietberg Instituut voor Rationele Suikerproductie Bergen op Zoom, Holland

plants per pot at the late two-leaf stage, and finally, on March 13, to two plants per pot at the eight-leaf stage. On March 13 the pots for each variety were assigned at random to one of the six climates, with four pots of a variety or a total of 32 pots for the eight varieties to a single climate. These pots were further assigned at random in units of eight pots (varieties) to two trucks of four pots to a truck, or a total of eight trucks for the 32 pots to a climate.

Table 2.—Controlled Climates.

Climate	Period from 8 a.m. to 4 p.m. (8 hrs.)	Period from 4 p.m. to 8 a.m. (16 hrs.)
1	20° C (Sunlight)	14° C (Natural day length)[1]
2	20° C (Sunlight)	14° C (Dark)
3	20° C (Sunlight)	20° C (Dark)
4	26° C (Sunlight)	20° C (Natural day length)[1]
5	26° C (Sunlight)	20° C (Dark)
6	26° C (Sunlight)	26° C (Dark)

[1] Natural day length at Pasadena, California, increased gradually from 10.6 hours for the time of planting, February 2, 1951, to 11.9 hours when the plants were placed into the above climates, March 13, 1951, to 14.3 hours when the plants were harvested, June 5, 1951. From February 2 to March 13, 1951, the plants were grown in a greenhouse kept at 23° C. from 8 a. m. to 4 p. m. and at 17° C. from 4 p. m. to 8 a. m.

Weekly counts of newly formed leaves and of old leaves were made during the 84-day growth period of the plants in their respective climates. The old leaves were removed, saved, dried and added to the dried material of the tops of the harvested plants. At the time of harvest on June 5, 1951, the beet plants were separated into roots and tops by cutting just below the base of the leaves which were still attached to the plant. The beet roots, including the crown, were weighed and analyzed for sucrose content by the hot extraction method (1) after freezing individual 26.0-gram samples of pulp prepared from the two beet roots of each pot. The tops were weighed and separated into distinct fractions of living leaf blades and a residue of

unclassified material. Each leaf fraction was weighed fresh and again after it had been dried in a forced-draft oven maintained at 80° C.

The results of each measurement, summarized in Table 3, were analyzed statistically for each variety separately and for all varieties collectively by the method of analysis of variance (3). The error variances (mean square error), mean values, coefficients of variation and the observed F-values were obtained for each measurement, as follows, using the beet root yields of the US 22/3 variety as an illustration:

Source of variation	Degrees of freedom	Sum of squares	Mean square (Variance)	Observed F-value
Total	23	764,998	.....	.....
Climates	5	497,156	99,431	6.68
Error	18	267,842	14,880	.....

$$\text{Coefficient of variation (CV)} = \frac{(\text{error variance})^{1/2}}{\text{mean}} \times 100 = \frac{(14{,}880)^{1/2}}{305.6} \times 100 = 39.9$$

Mean = general mean of 24 values

For the beet root yields of all varieties the procedure used is:

Source of variation	Degrees of freedom	Sum of squares	Mean square (Variance)	Observed F-value
Total	191	8,541,129	.....	.....
Climates	5	3,990,563	798,113	96.23
Varieties	7	2,299,011	328,430	.....
Climate x variety	35	1,057,146	30,204	.....
Error	144	1,194,409	8,294	.....

$$CV = \frac{(\text{error variance})^{1/2}}{\text{mean}} \times 100 = \frac{(8{,}294)^{1/2}}{286.6} \times 100 = 31.8\%$$

Mean = general mean of 192 values

Experimental Results

The inherent variability of the plants of each beet variety is indicated by the coefficient of variation of the plants which were grown in the six climates (Table 3). A careful inspection of these coefficients shows no great difference in variability consistently in favor of any of the varieties for beet root weights, percent sucrose, sucrose weights, fresh and dry weight of the tops, fresh weight of the living blades, the number of leaves at harvest, the total number of leaves produced and the final heights of the plants. Even genetically uniform material of fair viability, such as the Holland Inbred, has a coefficient of variation of root weights equal to 28.4 percent, in contrast to the values of 39.9 percent and 25.6 percent for the open-pollinated varieties U.S. 22/3 and G.W. 304, respectively. This picture is not improved for the hybrid varieties, since H. 148 and U. S. 35 MS x CT9 have coefficients of variation of 24.3 percent and 29.6 percent, respectively.

The coefficients of variation of sucrose percents are about the same for all varieties, except the Holland Inbred, which has a coefficient of variation of 6.9 percent compared to 10.2 and 12.4 percent for the open-pollinated varieties, G.W. 304 and U. S. 22/3, respectively. This advantage in favor of the Holland Inbred may be valuable in studies where its slower growth rate, compared to the hybrid and open-pollinated varieties, is not important.

Table 3.—Summary of the Statistical Analyses of the Beet Root Weight, Sucrose Concentration, Sucrose Produced, Weight of Tops, Leaf Count and Height Measurements for Eight Sugar Beet Varieties in Six Climates.

Measurement	Statistic	US 22/3	GW 304	♀ 148	♂ 148	H 148	CT9 Inbred	US 35 MS x CT9	Holland Inbred	All varieties
Root	Error var.	14,880	14,420	6,210	7,912	8,488	1,038	9,986	3,418	8,294
wts	Mean[1]	306	468	215	296	378	87	337	206	287
(gm)	CV[2]	39.9	25.6	36.6	30.0	24.3	37.0	29.6	28.4	31.8
	F-value[3]	6.68[5]	12.11[5]	9.17[5]	20.5[5]	33.6[5]	7.00[5]	18.3[5]	12.0[5]	96.2[5]
Sucrose	Error var.	1.12	0.85	0.60	0.84	0.66	1.09	0.76	0.48	0.80
(%)	Mean[1]	8.5	9.1	7.6	8.4	7.8	8.8	9.2	10.0	8.68
	CV[2]	12.4	10.2	10.2	10.9	10.4	11.8	9.5	6.9	10.3
	F-value[3]	3.80[4]	6.06[5]	7.90[5]	6.68[5]	8.97[5]	2.95[4]	6.70[5]	6.92[5]	36.3[5]
Sucrose	Error var.	202.8	149.4	48.3	105.4	105.9	10.3	110.2	50.1	97.81
(gm)	Mean[1]	27.3	44.2	17.4	26.2	32.4	8.0	32.7	21.5	26.20
	CV[2]	52.1	27.6	39.9	39.2	31.8	40.1	32.1	32.9	37.7
	F-value[3]	5.56[5]	15.99[5]	11.62[5]	16.99[5]	27.13[5]	8.06[5]	20.12[5]	12.18[5]	96.9[5]
Tops,	Error var.	30,542	53,992	55,980	30,156	39,182	5,966	22,303	23,038	32,645
fresh	Mean[1]	776	980	850	777	913	281	786	688	756
wt (gm)	CV[2]	22.5	23.7	27.8	22.4	21.7	27.5	19.0	22.1	23.9
	F-value[3]	5.11[5]	4.40[5]	3.64[4]	3.12[4]	8.39[5]	5.90[5]	11.89[5]	9.43[5]	38.3[5]
Tops,	Error var.	408	547	716	263	398	65	316	312	378
dry wt	Mean[1]	96	135	102	107	122	34	95	95	98.4
(gm)	CV[2]	21.0	17.3	26.3	15.1	16.4	23.7	18.7	18.6	19.8
	F-value[3]	3.79[4]	4.72[5]	2.98[4]	13.51[5]	10.10[5]	5.05[5]	10.84[5]	7.57[5]	43.5[5]
Blades,	Error var.	4,958	6,253	5,016	1,718	4,295	660	1,529	1,960	3,298
fresh	Mean[1]	237	348	295	279	313	88	217	194	246.4
wt (gm)	CV[2]	29.7	22.7	24.0	14.8	20.9	29.2	18.0	22.8	23.3
	F-value[3]	2.71	4.65[5]	2.72	9.23[5]	6.18[5]	2.88[4]	11.53[5]	5.84[5]	30.3[5]
Blades,	Error var.	84	198	129	37	67	53	38	77	85.3
number	Mean[1]	62	60	61	56	64	41	55	67	58.3
	CV[2]	14.8	23.5	18.6	10.9	12.8	17.8	11.2	13.1	15.8
	F-value[3]	4.88[5]	2.57	3.44[4]	8.94[5]	12.22[5]	6.89[5]	20.50[5]	12.60[5]	49.6[5]
Total	Error var.	81	337	158	75	102	142	76	92	132.7
number	Mean[1]	106	102	98	102	111	76	94	109	99.9
leaves	CV[2]	8.5	18.0	12.8	8.5	9.1	15.6	9.3	8.8	11.5
	F-value[3]	1.63	0.59	0.49	1.82	1.29	1.04	1.98	2.83[4]	4.5[5]
Height	Error var.	30	38	47	73	32	21	36	28	38.1
(cm)	Mean[1]	51	60	48	51	49	41	56	56	51.6
	CV[2]	10.8	10.4	14.2	16.6	11.5	11.1	10.7	9.5	12.0
	F-value[3]	1.09	1.08	0.69	1.00	1.89	2.91[4]	1.38	6.48[5]	7.8[5]

[1] Average of 24 pots.
[2] Coefficient of variability.
[3] The F-values represent the ratios of climate variance to error variance. The required values at the 5 percent and 1 percent levels are 2.77 and 4.25, respectively, for a given variety, and 2.28 and 3.15, respectively, for all varieties.
[4] Significant at 5 percent level.
[5] Significant at the 1 percent level.

The coefficients of variation of the sucrose weights per pot, as might be expected, are higher than either the coefficients of variation of beet root weights or of sucrose percents. The coefficients of all varieties are about the same, except for U. S. 22/3, which is considerably higher than the others. The reason for this is probably due to the fact that the coefficients of variation of beet root weights and of sucrose percents of U. S. 22/3 are the highest of all varieties. Certainly a value of 52.1 percent for U. S. 22/3, in contrast to the lowest value of 27.6 percent for the GW 304, does not point conclusively to a higher variability of commercial varieties in comparison to the inbred and hybrid varieties used in this study.

The coefficients of variation of the fresh weights and dry weights of the tops again do not differ greatly from each other. As a rule, the coefficients of variation of the dry weights of the tops are less than those of the fresh weights; however, the difference, while consistent, is not large. The coefficients of variation of the fresh weights of the living blades differ considerably from each other, but this variation is not related to the genotype of the beets. The variability of the number of living blades is the highest in the GW 304 variety and the lowest in the male 148 inbred and the U. S. 35 MS x CT9 hybrid, while the remaining varieties have intermediate variabilities. The total number of leaves produced by the plants during their entire growth period and the heights of the plants at harvest have the lowest variabilities of any of the measurements made, except for sucrose concentrations, but again there is no consistent advantage of one variety over the others.

Discussion

A careful review of the coefficients of variation shows no distinct advantage of the inbred or hybrid varieties over the open-pollinated varieties in these experiments. Theoretically, the inbreds and hybrids should have shown a decrease in variability, and their failure to do so indicates that the improvement in genetic composition of the varieties has been slight or that the variations associated with the technique used in growing the plants has masked the reduction in variability induced by plant breeding. Since the coefficients of variation do not decisively favor one variety over another, the best variety to use in physiological studies must be selected on other bases. At present the variety which has the greatest growth potential in the widest range of conditions, as, for example, GW 304, should be selected, rather than a variety that grows poorly.

While the coefficient of variation and rate of growth are important criteria for the selection of a variety of beets to be used for plant physiological studies, the selection of a measurement suitable for detecting growth changes should consider also the F-values of the treatment to error-variance ratio (Table 3). Thus, the coefficients of variation of the beet root weight and sucrose weight of the varieties individually and collectively are the highest in all measurements taken; however, the calculated F-values are also the highest throughout, indicating that the effects of climate on beet root and sucrose weights are even larger than the error variabilities which occurred in these measurements. In contrast, the sucrose percents have the lowest coefficients of variation of any measurements, and yet the F-values are, on the average, less than one-half of the F-values of the beet root and sucrose weights. This suggests that the sucrose concentration of the beet roots is less affected by differences in climate than beet root weights and sucrose

respectively, for a given variety, and 2.28 and 3.15, respectively, for all varieties.
[a] Significant at 5 percent level.
[b] Significant at the 1 percent level.

yields. The fresh and dry weights of the tops, the fresh weight of the blades, and the number of living blades at the time of harvest have intermediate F-values, while the total number of leaves produced by the plants during the growing season and the height of the plants at the time of harvest have the lowest F-values, which in most instances are not significant at the 5 percent level. This again indicates that the coefficient of variation should not be used exclusively as a criterion for selecting the measurement to be made to detect changes in plant growth.

Summary

The variability of eight sugar beet varieties, consisting of two open-pollinated commercial varieties, four inbreds and two hybrids, was studied in six climates. A review of the coefficients of variation obtained showed no consistent decrease in variability in favor of the inbreds and hybrids over the open-pollinated varieties, indicating that the improvement in the genetic uniformity of the inbreds and hybrids has been slight or that the technique used in growing the plants has masked the reduction in variability induced by plant breeding. Accordingly, the logical variety to use in plant physiological studies is the one which grows rapidly in a wide range of conditions rather than a variety that grows poorly.

In the selection of a measurement to make on plants to observe growth changes the ratio of the treatment variance to its error variance (F-value) must be considered as well as the coefficient of variation. Thus, at times, the effect of climate on the growth of sugar beet plants may be observed better by recording factors with a very high coefficient of variation, such as beet root weight or sucrose produced, rather than by measuring some factor with a low coefficient of variation, such as counting the total number of leaves developed by the plants or by measuring their heights at the time of harvest.

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Growth and Development of Open-pollinated, Hybrid and Inbred Sugar Beet Varieties in Controlled Climates[1]

ALBERT ULRICH[2]

Agronomists and geneticists are often interested in improving crops by selecting better varieties from those already existing or from those being developed by plant breeding. Ordinarily, measurements of variety performance are obtained by conducting field trials for one or more years in a single locality or in widely separated areas. If the investigator is fortunate enough to draw a representative sample of climates for the area during the trials, a valid conclusion regarding the merits of each variety can be drawn. However, the desired climates with the proper sequences of light, temperature and rainfall do not occur in nature upon command, and consequently the advantages or disadvantages of certain varieties may not be discovered until the variety has been used in commercial plantings for some time.

The logical solution to the problem is to grow the varieties in preselected controlled climates (10)[3] in which moisture supply and nutrient level can be predetermined and controlled. The results of such an experiment, performed as part of a uniformity trial with eight sugar beet varieties in six climates, are reported in the present paper.

Procedure

The eight sugar beet varieties and the six climates used, as well as the procedure followed in these experiments, except for leaf counts, blade weights and plant heights, have been reported in a previous paper (9). Leaf counts and blade weights (Tables 6 and 7) were obtained by counting and weighing all immature leaf blades larger than ½ inch in width, all mature blades and all the old leaves having blades with 50 percent or more green tissue. Leaf blades with less than 50 percent green tissue were counted as dead leaves, added to the residue material, and weighed as part of the total dry matter of the tops. The heights of the sugar beet plants were determined by measuring the length of the tallest leaf on each plant in a pot, and the results were averaged for the two plants of the pot.

Results

Sucrose weights

The sucrose weights of the beet plants differed greatly for each variety grown in the different climates and between the varieties grown within a climate (Table 1). The major increases, regardless of the variety used, occurred in the climates with the long days. Increasing the photoperiod from eight hours to natural day length (10.6 to 14.3 hours) approximately trebled the sucrose produced by most of the varieties studied (Treatment 1 versus 2 and Treatment 4 versus 5), while an increase in the day tempera-

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[3] Numbers in parentheses refer to literature cited.

ture from 20° C. to 26° C., keeping the night temperature at 20° C. (Treatments 3 and 5), resulted in no significant change in sucrose production. Maintaining the day temperatures at 20° C. (Treatment 3) or 26° C. (Treatment 6) and lowering the night temperatures to 14° C. (Treatment 2) and 20° C. (Treatment 5), also failed to change the average amount of sucrose produced by the eight varieties in eight hours of sunlight. Only by lowering the day and night temperatures simultaneously, as in Treatment 2, were the sucrose yields increased; this may be seen by comparing Treatments 2 and 6 (Table 1). These observations, made primarily at day and night temperatures favorable to beet growth, agree closely with those made in earlier experiments (8).

Table 1.—Sucrose in Grams per Pot (Average of Four Pots).

Treatments		Sugar Beet Varieties								
8 am to 4 pm (8 hrs.)	4 pm to 8 am (16 hrs.)	US 22/3	GW 304	♀148	♂148	H148	CT9 Inbred	US 35 MS x CT9	Holland Inbred	Mean effect of climate
20° C	14° C (NL)[1]	34.4	76.8	33.4	58.1	69.6	15.6	60.1	39.9	48.5
20° C	14° C (Dark)	19.4	31.9	10.3	11.9	25.2	5.6	28.6	15.8	18.6
20° C	20° C (Dark)	19.9	34.1	12.4	10.7	14.6	5.7	12.5	14.1	15.7
26° C	20° C (NL)[1]	58.5	72.9	31.6	48.2	62.3	11.7	64.1	34.3	48.0
26° C	20° C (Dark)	16.9	31.1	8.9	14.8	15.9	5.6	12.6	12.1	14.7
26° C	26° C (Dark)	13.3	18.2	7.5	13.5	6.5	3.9	18.3	12.4	11.7
Observed F-value[2]		5.56	15.99	11.62	16.99	27.13	8.06	20.12	12.18	96.88
Significant difference[3]		21.4	18.2	10.3	15.3	15.3	4.8	15.6	10.5	4.9
Mean (24 pots)[4]		27.3	44.2	17.4	26.2	32.4	8.0	32.7	21.5	----
Mean as % of maximum		62	100	39	59	73	18	74	49	----
Rank		4	1	7	5	3	8	2	6	----

[1] NL = natural day length at Pasadena, California, which increased gradually from 10.6 hours at the time of planting on February 2 to 11.9 hours when the plants were placed in the different climates on March 13 to 14.3 hours when the plants were harvested on June 5, 1951.
[2] Required F-values at the 5 percent and 1 percent levels are 2.77 and 4.25, respectively, for a given variety and 2.28 and 3.15, respectively, for the eight varieties (mean effect of climate).
[3] At the 5 percent level.
[4] A difference of 7.5 grams is necessary for significance between variety means at the 5 percent level.

In comparing the sucrose productions of the eight varieties of beets, the open-pollinated and hybrid varieties, as expected, produced more sucrose than the inbred varieties. Within each varietal group there were further interesting differences, as for example between the two commercial varieties, U. S. 22/3 and G. W. 304. At a day temperature of 20° C, natural day length (treatment 1), the G. W. 304 variety produced more than twice as much sucrose as the U. S. 22/3 variety while, at a day temperature of 26° C, natural day length (treatment 4), the difference between the two varieties was less, although more sucrose was still produced by G. W. 304. In an 8-hour day, the G. W. 304 variety at all day or night temperatures again produced more sucrose than the U. S. 22/3 variety. Using the mean value of the 24 pots of the G. W. 304 variety in the six climates as 100 percent, the U. S. 22/3 variety has a relative sucrose yield of only 62 percent. Thus, the G. W. 304 variety has a wider climatic range and a higher overall sucrose production than the U. S. 22/3 variety and therefore should be the preferable variety to use commercially, unless disease and pests alter this relationship in the field.

The two hybrid varieties, H148 and U. S. 35 MS x CT9, produce about

the same amount of sucrose in all six climates, except in the 8-hour photoperiod and constant day and night temperature of 26° C. Under these conditions H148 produced about ⅓ of the sucrose of the U. S. 35 MS x CT9 hybrid.

A statistical analysis of the sucrose produced by the eight varieties in the six climates showed that the effects of climate and the differences between the varieties were highly significant (Table 10). The interaction between varieties and climates was also highly significant, indicating that some or all varieties did not respond equally to each climate. This was especially true in the comparison of the U. S. 22/3 to G. W. 304 (Table 1), in which there were significant decreases in sucrose production in U. S. 22/3 in Treatment 1 compared to Treatment 4, but not in G. W. 304. However, separate statistical analyses of the varieties in which the variety-climate interaction

Table 2.—Beet Root Weights in Grams of Fresh Material (Average of Four Pots).

Treatments		Sugar Beet Varieties								
8 am to 4 pm (8 hrs.)	4 pm to 8 am (16 hrs.)	US 22/3	GW 304	♀148	♂148	H148	CT9 Inbred	US 35 MS x CT9	Holland Inbred	Mean effect of climate
20° C	14° C (NL)[1]	394	742	375	616	768	159	572	356	498
20° C	14° C (Dark)	205	343	155	148	330	61	289	149	210
20° C	20° C (Dark)	236	431	172	162	204	68	141	145	195
26° C	20° C (NL)[1]	590	700	357	480	643	117	633	315	480
26° C	20° C (Dark)	208	379	129	208	223	64	151	133	187
26° C	26° C (Dark)	201	214	103	161	99	49	234	138	150
Observed F-value[2]		6.68	12.11	9.17	20.46	35.65	7.00	18.30	11.98	96.23
Significant difference[3]		181	178	117	132	137	48	148	87	45
Mean (24 pots)[4]		306	468	215	296	378	87	337	206	----
Mean as % of maximum		65	100	46	63	81	19	72	44	----
Rank		4	1	6	5	2	8	3	7	----

[1] [2] [3] For explanation, see Table 1.
[4] A difference of 52 grams is necessary for significance between variety means at the 5 percent level.

aappeared the largest (Table 1, U. S. 22/3 versus G. W. 304 and male parent 148 versus H148) failed to disclose a significant interaction of variety and climate. A reasonable explanation for the lack of significance of the interactions of several of the paired comparisons seems to be that the larger F-value required for significance masked the interactions that actually existed between the paired varieties in two climates.

Of the four inbred varieties (Table 1), the male parent of H148 produced the most sucrose in all six climates, but this was still only 59 percent of that produced by G. W. 304. Next is the Holland Inbred variety with a relative value of 49 percent, third is the female parent of H148 with a relative value of 39 percent, and a poor fourth is CT9 Inbred with a relative value of 18 percent. Within the four inbred varieties it is interesting that the relative differences in sucrose production were maintained in all six climates except for minor deviations by some inbred, indicating that there is no pronounced interaction between variety and climate as indicated by the G. W. 304 and U. S. 22/3 varieties.

Beet root weights

The beet root weights of the eight varieties in the six climates are given in Table 2. In general, the results of the beet root weights parallel those of the sucrose weights even so far as to place each variety in the same rank, except for a few minor changes. Again, a pooled analysis of variance of the eight varieties in the six climates showed a highly significant variety-climate interaction (Table 10). Separate statistical analyses of paired varieties, particularly U. S. 22/3 and G. W. 304, again failed to show a significant variety-climate interaction even though the beet root weight in U. S. 22/3, but not in G. W. 304, was significantly less in Treatment 1 than in Treatment 4 (Table 2). Similarly, the H148 variety in Treatment 6 weighed significantly less than in Treatment 5, but this was not true

Table 3.—Sucrose as Percent of Fresh Root Weight (Average of Four Pots).

Treatments		Sugar Beet Varieties								
8 am to 4 pm (8 hrs.)	4 pm to 8 am (16 hrs.)	US 22/3	GW 304	♀148	♂148	H148	CT9 Inbred	US 35 MS x CT9	Holland Inbred	Mean effect of climate
20° C	14° C (NL)[1]	8.6	10.4	8.9	9.2	9.0	9.7	10.5	11.2	9.71
20° C	14° C (Dark)	9.3	9.2	6.7	8.0	7.7	8.7	10.0	10.4	8.77
20° C	20° C (Dark)	8.9	7.9	6.5	6.6	7.0	8.1	8.7	9.7	7.92
26° C	20° C (NL)[1]	9.7	10.4	8.9	10.0	9.5	9.9	10.0	10.9	9.93
26° C	20° C (Dark)	7.9	7.9	6.9	8.0	6.9	8.6	8.0	9.1	7.95
26° C	26° C (Dark)	6.8	8.5	7.3	8.4	6.6	7.6	7.9	9.0	7.78
Observed F-value[2]		3.80	6.06	7.90	6.68	8.97	2.95	6.70	6.92	36.31
Significant difference[3]		1.57	1.36	1.15	1.36	1.21	1.54	1.29	1.03	0.44
Mean (24 pots)[4]		8.5	9.1	7.6	8.4	7.8	8.8	9.2	10.0	.....
Mean as % of maximum		85	91	76	84	78	88	92	100	.....
Rank		5	3	8	6	7	4	2	1	.....

[1] [2] [3] For explanation, see Table 1.
[4] A difference of 1.6 percent is necessary for significance between variety means at the 5 percent level.

for the U. S. 22/3 variety, where the weights were about the same. Thus, as far as beet root weights are concerned, H148 produces larger storage roots than U. S. 22/3 (Treatment 1) when grown in cool climates with a long day, while in warm climates with a short day (Treatment 6) U. S. 22/3 does better than H148.

Regardless of the variety used, the largest change in beet root weight, just as in the sucrose weights, was produced by an increase in day length. Increasing the day temperature from 20° C. to 26° C. (Treatments 3 and 5) had no significant effect on beet root weight, which is contrary to an earlier report (8). The failure to show a significant change in beet root weight with day temperature change is most likely due to the shorter growth period of these plants, 123 days compared to 180 days in the earlier experiments (8). Apparently, longer periods of growth are necessary to show significant differences in root weight for small differences in temperature.

Sucrose percentages

The average sucrose concentration of each variety in each climate is given in Table 3. These values differ considerably between varieties and to a lesser extent between climates in any given variety. The highest average

sucrose concentration, 10.0 percent, was found in the Holland Inbred variety, and the lowest value, 7.6 percent, in the female parent of H148. Arranging the varieties according to sucrose concentration and comparing this order to that found for beet root and sucrose weights brings out a relationship often observed in sugar beets; namely, high beet root weights —low sucrose concentration, and low beet root weights—high sucrose concentration. An apparent exception to this rule is G. W. 304, which ranks first in beet root and sucrose weights and almost second in sucrose concentration.

The effects of climate on the sucrose concentration of beet roots of the eight varieties (Table 3) agree closely with those reported earlier (8). In every instance but one the sucrose concentration of the beet roots is

Table 4.—Tops of Fresh Weight in Grams Per Pot at Harvest, June 5, 1951 (Average of Four Pots).

Treatments		Sugar Beet Varieties								
8 am to 4 pm (8 hrs.)	4 pm to 8 am (16 hrs.)	US 22/3	GW 304	♀148	♂148	H148	CT9 Inbred	US 35 MS x CT9	Holland Inbred	Mean effect of climate
20° C	14° C (NL)[1]	1085	1277	1173	932	1332	444	1156	1096	1062
20° C	14° C (Dark)	726	1077	786	624	886	254	864	545	719
20° C	20° C (Dark)	820	1015	1015	848	1063	298	653	699	801
26° C	20° C (NL)[1]	881	1079	897	947	895	286	985	763	841
26° C	20° C (Dark)	605	875	667	716	846	253	520	604	636
26° C	26° C (Dark)	543	559	561	597	458	156	540	419	479
Observed F-value[2]		5.11	4.40	3.64	3.12	8.39	5.90	11.89	9.43	38.32
Significant difference[3]		260	345	352	258	294	115	222	225	89
Mean (24 pots)[4]		776	980	850	777	913	281	786	688	....
Mean as % of maximum		79	100	87	79	93	29	80	70	....
Rank		6	1	3	5	2	8	4	7	....

[1] [2] [3] For explanation, see Table 1.
[4] A difference of 103 grams is necessary for significance between variety means at the 5 percent level.

higher in plants grown at a natural day length than in only eight hours of sunlight (Treatments 1 and 2 and Treatments 4 and 5). For plants at 20° C. during the day and 14° C. during the night (Treatments 1 and 2), the longer day in Treatment 1 increased the average sucrose concentration of the roots by one percentage unit and in comparable plants at 26° C. during the day and 20° C. at night (Treatments 4 and 5) the average increase was two percentage units. Apparently at 26° C. (Treatments 4 and 5) the longer day was more effective in increasing sucrose concentration than at the lower temperature (Treatments 1 and 2).

In natural day length (Treatments 1 and 4) the effect of temperature on sucrose concentration in these experiments was not significant. Of the plants grown in eight-hour photoperiods, the ones in the higher temperatures had lower sucrose concentrations in all eight varieties in Treatments 3 and 2, and five out of eight varieties in Treatments 6 and 5 (Table 3). On the average this caused a significant decrease of 0.85 percentage units in Treatment 3 compared to two, and a nonsignificant decrease of 0.17 percentage units in Treatment 6 compared to five. Apparently in shorter days, when less sucrose is synthesized, relatively small temperature changes may have at times a greater effect on sucrose concentration than

in natural day periods (comparing Treatments 2, 3, 5 and 6 with Treatments 1 and 4).

Fresh weight of tops

The fresh weight of the tops of each variety in the six climates at the time of harvest on June 5, 1951, is given in Table 4. Again, the plants which were grown in natural day lengths made the largest top growth. As a rule, the relative increases in top growth in the longer day periods were about the same as the sucrose percentages (Table 3) but not nearly as great as the gains in beet root weights (Table 2) or in sucrose stored in the roots (Table 1). Apparently, top growth is influenced less by day length than beet root growth or sucrose storage. This agrees with observations reported earlier (8).

Table 5.—Tops as Dry Weight in Grams Per Pot of All Leaves Produced (Average of Four Pots).

Treatments		Sugar Beet Varieties								
8 am to 4 pm (8 hrs.)	4 pm to 8 am (16 hrs.)	US 22/3	GW 304	♀148	♂148	H148	CT9 Inbred	US 35 MS x CT9	Holland Inbred	Mean effect of climate
20° C	14° C (NL)[1]	113	159	132	135	166	49	124	130	126.2
20° C	14° C (Dark)	80	121	83	69	106	30	92	71	81.4
20° C	20° C (Dark)	99	131	109	94	101	34	73	87	91.1
26° C	20° C (NL)[1]	123	171	125	148	156	38	138	117	127.1
26° C	20° C (Dark)	88	126	85	107	119	31	68	91	89.4
26° C	26° C (Dark)	72	102	79	88	87	23	76	71	74.9
Observed F-value[2]		3.79	4.72	2.98	13.51	10.10	5.05	10.84	7.57	43.51
Significant difference[3]		30	35	40	24	30	12	26	36	9.6
Mean (24 pots)[4]		96	135	102	107	122	34	95	95	.....
Mean as % of maximum		71	100	76	79	90	25	70	70	.....
Rank		5	1	4	3	2	8	6	7	.....

[1] [2] [3] For explanation, see Table 1.

[4] A difference of 11 grams is necessary for significance between variety means at the 5 percent level.

The temperature at which the beet plants are grown is also important for top growth. Generally, top growth is less at very high and very low temperatures (8). In these experiments the deleterious effects of high temperatures are particularly noticeable in the plants grown in natural day lengths at day temperatures 26° C. compared to 20° C. (Treatments 1 and 4) and for plants in 8 hours of sunlight at a constant temperature of 26° C. (Treatment 6) compared to 20° C. (Treatment 3).

The fresh weight of the tops (Table 4) of the different varieties agrees rather closely with the amounts of beet root (Table 2) and of sucrose (Table 3) produced by each variety. Particularly interesting is the decrease in range in the tops compared to the roots. The lowest value of the tops, when expressed as percent of the maximum, is 29 percent, and for beet roots the comparable value is 19 percent. The major change in the rank of the varieties was made by U. S. 22/3, which dropped from fourth position in beet root weight to sixth position in fresh weight of the tops. In spite of this decrease in rank U. S. 22/3 still produced 79 percent of the

maximum top growth produced by variety G. W. 304, while in beet root weight U. S. 22/3 ranked fourth but produced only 65 percent of the maximum root weight produced by G. W. 304. Usually there is a direct relationship between top growth and beet root growth; namely, large tops indicate large storage roots. However, large tops do not always produce large roots, as shown by the fact that in the seven highest yields from the eight varieties the range in top weight is only 70 percent to 100 percent of the maximum, while in the seven highest beet root yields the comparable range is 44 percent to 100 percent, showing that there is no simple relationship between top growth and amount of root developed.

Dry weight of tops

The total dry matter produced by the tops during the entire growth period of the plants (Table 5) agrees with their fresh weight, so the interpretation of the results is the same as given for the fresh weight of the tops.

Table 6.—Fresh Weight of Living Blades in Grams Per Pot (Average of Four Pots).

Treatments		Sugar Beet Varieties								
8 am to 4 pm (8 hrs.)	4 pm to 8 am (16 hrs.)	US 22/3	GW 304	♀148	♂148	H148	CT9 Inbred	US 35 MS x CT9	Holland Inbred	Mean effect of climate
20° C	14° C (NL)[1]	313	485	370	350	431	123	303	281	332
20° C	14° C (Dark)	227	359	251	194	312	78	231	165	227
20° C	20° C (Dark)	248	356	345	276	328	96	172	209	254
26° C	20° C (NL)[1]	286	359	324	354	342	89	284	219	282
26° C	20° C (Dark)	184	305	247	257	281	80	138	160	207
26° C	26° C (Dark)	163	224	233	240	182	58	175	131	176
Observed F-value[2]		2.71	4.65	2.72	9.23	6.18	2.88	11.53	5.84	30.29
Significant difference[3]		105	118	105	62	97	38	58	66	28.4
Mean (24 pots)[4]		237	348	295	279	313	88	217	194	.....
Mean as % of maximum		68	100	85	80	90	25	62	56	.....
Rank		5	1	3	4	2	8	6	7	.....

[1] [2] [3] For explanation, see Table 1.

[4] A difference of 33 grams is necessary for significance between variety means at the 5 percent level.

Fresh weight of the living blades

The fresh weights of the living blades (Table 6) produced by each variety in each of the six climates agrees closely with the fresh and dry weights of the tops, but these values are again related only in a general way to the beet root weights. Perhaps an integrated value of the living blade material produced during the entire growth period of the sugar beet plants, instead of the final fresh weight of the blades, may be more closely related to the beet root weights. The testing of this idea, however, must wait for future studies.

Number of living blades

The number of living blades at the time of harvest (Table 7) was influenced by the climate in which the plants were grown. The greatest number of living leaves was found in plants which grew in a cool climate with natural day length. Significant decreases in leaf counts were observed in plants in 8 hours of sunlight, particularly in the plants kept at a temperature of 26° C.

Of the eight varieties studied the Holland Inbred, which ranked seventh in fresh weight of the tops and beet root weight, had the greatest number of living leaves. In contrast to this, the G. W. 304 variety, which ranked first in top and root weight, was fifth in the number of leaves living at the time the beets were harvested. At first glance this may indicate an inverse relationship between the number of leaves found and top growth, but this idea is contradicted by the H148 variety, which ranks second in the number of living leaves, beet root weight and fresh weight of the tops.

Total number of leaves produced

The total number of leaves produced by the sugar beet plants, surprisingly enough, was about the same in all climates (Table 8). The lowest number of leaves was produced in the warmest climate (Treatment 6), which was an average of 92.2 leaves in all varieties. In the other climates the averages, which fell between 99.2 and 104.1, were not significantly different from each other.

The total numbers of leaves produced by the varieties, while significantly different in some instances, did not differ greatly from each other. The CT9 Inbred variety produced the lowest number of leaves, 76.2, and the H148 variety the highest number of leaves, 111.5, showing that the total

Table 7.—Number of Living Blades Per Pot at Harvest, June 5, 1951 (Average of Four Pots).

Treatments		Sugar Beet Varieties								
8 am to 4 pm (8 hrs.)	4 pm to 8 am (16 hrs.)	US 22/3	GW 304	♀148	♂148	H148	CT9 Inbred	US 35 MS x CT9	Holland Inbred	Mean effect of climate
20° C	14° C (NL)[1]	72	73	73	69	83	55	76	88	73.6
20° C	14° C (Dark)	68	65	67	58	69	49	63	77	64.4
20° C	20° C (Dark)	62	58	60	60	69	39	54	65	58.3
26° C	20° C (NL)[1]	71	65	68	56	68	39	55	71	61.5
26° C	20° C (Dark)	56	59	54	54	55	40	47	57	52.6
26° C	26° C (Dark)	45	39	45	41	41	27	35	44	39.6
Observed F-value[2]		4.88	2.72	3.44	8.94	12.22	6.89	20.50	12.60	50.00
Significant difference[3]		13.6	20.7	16.9	8.9	12.1	10.8	9.2	13.0	4.6
Mean (24 pots)[4]		62	60	61	56	64	41	55	67	.....
Mean as % of maximum		93	90	91	84	96	61	82	100	.....
Rank		3	5	4	6	2	8	7	1	.....

[1] [2] [3] For explanation, see Table 1.

[4] A difference of 5.3 leaves is necessary for significance between variety means at the 5 percent level.

number of leaves produced by a beet plant is not by itself a good indicator of the relative growth of the plants. However, the difference between the total number of leaves produced and those living when the plants are harvested is a measure of the life expectancy of an individual leaf of a given variety in a specific climate. From this viewpoint the average life expectancy is considerably greater for leaves of plants grown in cool climates with long days, while the shortest life span is of leaves in the warmest climate in an 8-hour day.

Height of plants

The heights of the sugar beet plants at the time of harvest June 5, 1951, are given in Table 9. The results of these measurements show that the average height of the plants in any given variety of beets was not altered greatly by growing the plants in the controlled climates. The F-values (Table 9), when calculated from an analysis of variance of each variety of beets in the six climates, was significant for only the CT9 Inbred and Holland Inbred, even though the mean effect of climate on the plant heights was highly significant (Tables 9 and 10). A further inspection of the mean effect of climate on heights of the plants shows that long days were conducive to tall leaves (Table 9). The plants with the shortest leaves were those grown with 8 hours of sunlight at a temperature of 20° C. during the day and 14° C. during the night (Treatment 2). The next shortest plants were those grown in 8 hours of sunlight at a constant temperature of 26° C. (Treatment 6). Just what factors are involved in determining leaf heights in the controlled climates is not clear at present and must be left to future experiments.

In a review of the plant heights of the different beet varieties the shortest plants were the CT9 Inbred, while the tallest plants were the G. W. 304 variety. This agrees with the relative growth of the two varieties (Tables 1, 2, 4, 5, 6). A further review of the heights of the other varieties

Table 8.—Total Number of Leaves Produced, Old Plus Living, Larger Than ½ Inch in Width (Average of Four Pots).

Treatments		Sugar Beet Varieties								
8 am to 4 pm (8 hrs.)	4 pm to 8 am (16 hrs.)	US 22/3	GW 304	♀148	♂148	H148	CT9 Inbred	US 35 MS x CT9	Holland Inbred	Mean effect of climate
20° C	14° C (NL)[1]	101	100	102	104	117	84	104	117	103.4
20° C	14° C (Dark)	103	99	98	95	109	81	95	116	99.2
20° C	20° C (Dark)	110	104	97	106	112	69	90	106	99.2
26° C	20° C (NL)[1]	113	106	106	101	119	76	98	115	104.1
26° C	20° C (Dark)	107	112	94	110	107	78	93	108	100.8
26° C	26° C (Dark)	98	92	96	85	105	69	86	96	92.2
Observed F-value[2]		1.63	0.59	0.49	1.82	1.29	1.04	1.98	2.83	4.46
Significant difference[3]		(13)	(27)	(19)	(41)	(15)	(18)	(13)	14	5.7
Mean (24 pots)[4]		106	102	98	102	112	76	94	109	....
Mean as % of maximum		95	92	88	92	100	69	85	98	....
Rank		3	4	6	5	1	8	7	2	....

[1] [2] For explanation, see Table 1.

[3] At the 5 percent level. Figures in parentheses indicate that the F-values are not significant.

[4] A difference of 6.6 leaves is necessary for significance between variety means at the 5 percent level.

clearly indicates, however, that there are many exceptions to this observation, so height measurements alone are not very reliable for measuring the relative growth of a given variety of beets in different climates or for comparing the performance of different varieties of beet plants within one or more climates.

Discussion

The growth of the eight sugar beet varieties in the six climates is interesting in regard to the relative performances of the varieties in the different climates, particularly the U. S. 22/3 and G. W. 304 varieties. The results for the U. S. 22/3 and G. W. 304 varieties indicate that the G. W. 304 variety produces on the average much more sucrose and beet root growth than the U. S. 22/3. A further inspection of the results shows that the best performance of the G. W. 304 variety in the six climates is mainly in the cool climate, natural day length (Tables 1 and 2, Treatment 1). When the plants were grown in a warm climate, natural day length, the performance of U. S. 22/3 improved but did not quite equal the G. W. 304 variety (Tables 1 and 2, Treatment 4). When the plants were grown in 8 hours of sunlight at 26° C. the G. W. 304 variety grew relatively less than the U. S. 22/3 variety. Under these conditions U. S. 22/3 is about equal to G. W. 304 (Table 2, Treatment 6). From the practical standpoint, variety trials conducted in cool climates would undoubtedly favor the G. W. 304 variety while similar variety trials in warm climates would show no preference for either variety. Susceptibility to diseases and pests, which, of course, would favor U. S. 22/3 in California because of its resistance to curly top, and G. W. 304 in the mountain states, has not been considered in this discussion.

Table 9.—Height of Plants in CM. (Average of Four Pots).

Treatments		Sugar Beet Varieties								
8 am to 4 pm (8 hrs.)	4 pm to 8 am (16 hrs.)	US 22/3	GW 304	♀148	♂148	H148	CT9 Inbred	US 35 MS x CT9	Holland Inbred	Mean effect of climate
20° C	14° C (NL)[1]	53	58	51	51	53	47	57	56	53.1
20° C	14° C (Dark)	48	54	44	44	46	36	53	43	45.8
20° C	20° C (Dark)	55	61	51	50	50	42	52	57	52.5
26° C	20° C (NL)[1]	52	62	47	57	48	44	62	62	54.0
26° C	20° C (Dark)	52	63	50	53	55	42	55	60	55.4
26° C	26° C (Dark)	48	61	47	54	45	38	59	56	50.8
Observed F-value[2]		1.09	1.08	0.69	1.00	1.89	2.91	1.38	6.48	7.95
Significant difference[3]		(8)	(9)	(10)	(13)	(8)	7	(9)	8	3.0
Mean (24 pots)[4]		51.0	59.6	48.2	51.4	49.4	41.2	56.5	55.6	....
Mean as % of maximum		86	100	81	86	83	69	95	93	....
Rank		5	1	7	4	6	8	2	3	....

[1] [2] For explanation, see Table 1.

[3] At the 5 percent level. Figures in parentheses indicate that the F-values are not significant.

[4] A difference of 3.5 cm. is necessary for significance between variety means at the 5 percent level.

Another interesting point is the relationship of the inbred parents to their hybrid progeny when grown in the different climates. For example, the beet root weight of H148 in the cool climates was greater than either of its inbred parents (Table 2, Treatments 1, 2, 3), but in the warm climates the superiority of the hybrid was manifested only in the plants grown at natural day length (Treatment 4), while in an 8-hour day at 26° C. (night at 20° C., Treatment 5) the difference decreased until, for plants maintained continuously at 26° C. (Treatment 6), the hybrid produced

less than the parents. Thus, the relative performances of the inbreds and the hybrids produced from them would be altered, depending upon the climate in which the comparison was made. If the growing season were predominantly cool hybrid vigor would be observed, but if the comparison were made in a warm climate hybrid vigor would not be evident.

The sucrose concentrations of the inbreds and their hybrids are also interesting (Table 3). Generally, a hybrid beet root has a sucrose concentration intermediate between those of its parents (1, 2, 3, 4, 5, 6, 7). Again, in the warmer climates this intermediate sucrose concentration of the hybrid declines so far that at a photoperiod of 8 hours and a constant temperature of 26° C. (Table 3, Treatment 6) the hybrid contains less sucrose than either of its parents. Regarding the amount of sucrose produced by the hybrids and inbreds, the results vary according to the relative performances of these varieties with respect to sucrose concentration and the amount of beet root formed. Thus, hybrid vigor is again manifested in all climates studied except when the plants are grown in a warm climate for a photoperiod of 8 hours (Table 1, Treatment 6); under these conditions the hybrid produced less sucrose than either of its parents.

Table 10.—Analysis of Variance.

		Mean squares								
		Beet roots			Tops		Living blades		Total leaves	Height
			Sucrose							
Source of variation	DF	gm/pot	%	gm/pot	Fresh gm/pot	Dry gm/pot	Fresh gm/pot	number	number	cm
Total	191	.....	.....	.....	.....	.....	.....	.....	.....	.....
Climates	5	798,113[2]	29.05[2]	9,476.65[2]	1,250,929[2]	16,447[2]	99,894[2]	4,240.0[2]	591.6[1]	302.8[2]
Varieties	7	328,430[2]	15.56[2]	2,867.90[2]	1,081,515[2]	21,039[2]	161,243[2]	1,499.0[2]	2,937.6[2]	783.9[2]
Var x Cl	35	30,204[1]	1.18	313.22[1]	41,054	500	4,237	57.8	91.5	32.5
Error	144	8,294	0.80	97.81	32,645	378	3,298	84.8	132.7	38.1

[1] At the 1 percent level.
[2] At the 0.1 percent level.

Summary

Eight sugar beet varieties, two open-pollinated, four inbred and two hybrid varieties, were grown at a high level of nutrition in six controlled climates. The climates had either a natural day length of 10.6 to 14.3 hours or an 8-hour day. The temperatures, which were approximately optimum for beet growth, were 20° C. or 26° C. from 8 a. m. to 4 p. m. and 14° C., 20°, or 26° C. from 4 p. m. to 8 a. m. The sucrose produced by most of the varieties studied was nearly trebled by increasing the photoperiod from 8 hours to natural day length. As expected, the beets grown within the narrow range of temperatures used did not differ greatly in sucrose production. Only by decreasing the day and night temperatures simultaneously for the 8-hour day were the sucrose yields of the plants increased. The beet root weights, sucrose percentages, top weights, weights of living blades and numbers of living blades generally paralleled the sucrose weights; namely, increases were observed in the climates with long days over the short days and at the lower temperatures of the 8-hour days. Surprisingly enough, the

total numbers of leaves produced in each climate, except the warmest, were the same. Thus, the life expectancy of leaves of plants grown in climates with long days or with cool days or nights is much greater than in warm climates with short days.

The relative performance of each variety was not the same in each climate, as for example the better performance of G. W. 304 compared to U. S. 22/3 occurred mainly in the cool climates. Similarly, hybrid vigor was observed only in the cool but not in the warm climates. In fact, the hybrid H148 produced less sucrose than either of its parents when grown at 26° C. for an 8-hour day.

The importance of growing plants in controlled climates by agronomists and geneticists in order to improve crops is clearly indicated by the results of these experiments.

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Rate of Photosynthesis in Young Sugar Beet Plants

F. W. WENT[1]

One of the important factors determining beet yield is photosynthesis. To measure this single factor, the amount of dry weight produced in five to ten days by beet plants under standard conditions is being determined.

For this purpose five beets are planted per 4 x 4 inch plastic container in vermiculite. Once the plants have developed sufficiently so that they cover the 4 x 4 inch surface completely, the containers are divided into groups of four and eight each.

One or two groups are harvested immediately, the others are subjected to different light intensities at different temperatures for seven to eight days. When harvested after this time interval, the increase in dry weight is a measure of the rate of photosynthesis during this seven- to eight-day interval.

During this short experimental period the gain in dry-weight is not complicated by growth, and a fairly reliable figure for maximum potential CO_2 reduction is obtained. By these criteria photosynthesis in sugar beets is directly proportional to the light intensity up to well over 2,000 f. c., and it is proportional to the number of hours of light per day. The lower the temperature, the more photosynthesis takes place in U. S. 35, whereas U. S. 22 has its optimal rate of photosynthesis at 10° C. Different varieties differ in their rate of photosynthesis; U. S. 22 seems to have a consistently higher rate than U. S. 35.

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The Effects of Maleic Hydrazide and 2,4-D on Sugar Beet Growth and Sugar Content in Certain Field Experiments

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Previous work by Mikkelsen, et al. (2)[2] on organic soils of the Sacramento-San Joaquin Delta area of California has indicated that the yield and sucrose content of sugar beets can be favorably affected by growth regulators. Sucrose percentage and sugar yield per acre of treated beets have been increased. Under certain conditions root yields have also been increased. Erickson and Price (1) and Mikkelsen et al. (2) have presented data showing maleic hydrazide to be influential in hastening maturity, as indicated by increased root/top ratios. The physiological maturity of the beets, concentration of the growth regulator and the time of harvest influence the intensity of the responses obtained (2). Other tests have indicated that 2,4-D may temporarily induce higher sugar percentages. Such effects were observed to be of a short time duration.[3] Rasmussen (3) has shown that carbohydrates reserves are depleted under the influence of applications of this regulant.

This experiment was designed to evaluate the effects of maleic hydrazide and 2,4-D on sucrose accumulation and yield of sugar beets as influenced by the time lapse between treatment applications and harvest dates.

Table 1.—The Average Effect of Maleic Hydrazide and 2,4-D Treatments on Sucrose Content of Sugar Beets at Three Harvest Dates.

Treatments	Sucrose Content (percent) Harvest Dates 9/25/51	10/16/51	11/6/51	Ave. Treatment Effect
Check	12.1	13.5	13.9	13.1
MH (0.3%)	13.4	14.1	14.7	14.1
2,4-D (0.025%)	12.0	12.9	12.1	12.3
Ave. Time Effect	12.5	13.5	13.6	

L.S.D. (0.05) Dates and Treatments — 0.51
C.V. = 5.2%

Experimental Procedure

A commercial sugar beet planting, variety U. S. 22, on peaty muck of the Venice soil series, San Joaquin County, California, was used in this experiment. This site was selected because it is located in an area which has historically produced sugar beets of high yield, but relatively low sugar content. The sugar beets in the experimental plots were representative of the area, of uniform stand and appeared to be growing rapidly.

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[2] Numbers in parentheses refer to literature cited.

[3] R. S. Baskett—Unpublished data.

The experimental design consisted of completely randomized blocks, with three treatments, three dates of harvest and five replications. Each plot consisted of six 60-foot rows. Maleic hydrazide was applied as a foliar spray, at a concentration of 0.3 percent of active ingredient.[4] "Dreft," a commercial detergent, at a concentration of 0.05 percent, was used as a spreader in the maleic hydrazide mixture. The sodium salt of 2,4-D was applied at a concentration of 0.025 percent. These concentrations were used because previous work had indicated that they were near the optimum rates. Both materials were applied with knapsack sprayers, at the rate of 50 gallons an acre. This rate of application gave good coverage of the foliar parts. The original applications were made on September 4, 1951. The center 50 feet of the four middle rows were harvested for yield determinations. Four representative samples, each containing approximately 20 beets, were then taken from each plot for sugar and tare determinations.[5]

Results and Discussion

The effects of maleic hydrazide and 2,4-D on the sugar content of beets at 21-day harvest intervals are presented in Table 1. The maleic hydrazide treatment significantly increased the sugar content as compared with the untreated beets at all harvest dates. Its maximum effect was expressed 21

Table 2.—Average Effect of Maleic Hydrazide and 2,4-D Treatments on Sugar Beet Yields at Three Harvest Dates.

Treatments	Yields (tons per acre) Harvest Dates 9/25/51	10/16/51	11/6/51	Ave. Treatment Effect
Check	15.3	16.6	16.9	16.3
MH (0.3%)	15.9	15.4	16.0	15.8
2,4-D (0.025%)	16.5	16.2	18.6	17.1
Ave. Time Effect	15.9	16.0	17.2	

L.S.D. (0.05) Dates and Treatments — 1.02
C.V. = 8.4%

days after treatment, when the average sucrose increase over the check plots was 1.3 percent. This represents a 9.8 percent increase in sucrose content. Two,4-D treatments had a depressive effect on sucrose accumulation. This effect was not observed at the first harvest date, but at successive harvests the average sucrose content was reduced as compared to the checks. At the last harvest date a lowering of 1.8 percent occurred in beets from the 2,4-D-treated plots as compared to those of the check. There was no significant interaction between time and any treatment under the conditions of this experiment, even though the 2,4-D-treated beets appeared to decline in sugar content with time when compared to the check and the maleic hydrazide treated beets.

The average treatment effects of 2,4-D and maleic hydrazide on yield were not significantly different from the check as shown in Table 2. Beets

[4] Maleic hydrazide, as the diethanolamine formulation, was supplied by the Naugatuck Chemical Division, U. S. Rubber Company.

[5] Sucrose analyses were made by the Holly Sugar Corporation, at its Tracy, California, plant.

treated with 2,4-D gave significantly higher yields than those treated with maleic hydrazide. The greatest yield increase of beets sprayed with 2,4-D occurred between the second and third harvest dates, which corresponded to a period when the same beets appeared to decline in sucrose percentage.

Measurements of sugar yield per acre do not indicate an average increase of any one treatment over another, as shown in Table 3. Sugar yield determinations were not as accurate as those for percent of sucrose and yield because of the greater variability associated with this factor. A more

Table 3.—The Average Effect of Maleic Hydrazide and 2,4-D Treatments on the Sucrose Yield of Beets at Three Harvest Dates.

Treatments	Sucrose Yield (tons per acre) Harvest Dates 9/25/51	10/16/51	11/6/51	Ave. Treatment Effect
Check	1.83	2.21	2.30	2.12
MH (0.3%)	2.13	2.15	2.34	2.21
2,4-D (0.025%)	1.96	2.07	2.22	2.08
Ave. Time Effect	1.97	2.15	2.29	

L.S.D. (0.05) Dates and Treatments — 0.18
C.V. = 11.2%

critical examination of the data indicated, however, that maleic hydrazide-treated beets consistently produced more sucrose than the check at the first harvest date. This effect was not evident at subsequent harvests. Therefore, an analysis of variance was made on the data of the first harvest date from the maleic hydrazide treated and check plots. This material is found in Table 4. This analysis indicated that maleic hydrazide probably significantly increased the yield of sugar at three weeks after its application. A need is suggested for more work with maleic hydrazide, using shorter preharvest application intervals.

As compared to the check, 2,4-D treatments had no significant effect on the average sugar yield per acre.

Table 4.—The Effect of Maleic Hydrazide on Sucrose Yield of Beets at the First Harvest Date.

Treatment	Sucrose Yield (tons per acre) Harvest Dates I	II	III	IV	V	Ave. Treatment Effect
O	1.70	1.78	1.98	2.03	1.67	1.83
MH	1.82	2.05	2.08	2.24	2.44	2.13

L.S.D. (0.05) 0.29

Summary

Foliar sprays containing 0.3 percent maleic hydrazide and 0.025 percent 2,4-D were compared as to their effects on sugar beet growth and sucrose accumulation at three dates of harvest.

Maleic hydrazide applications increased the percentage of sucrose of sugar beets, but did not influence root yields under the conditions of this experiment. The largest increase in sugar percentage was measured during the first 21-day interval after treatment. The sugar yield per acre of the beets sprayed with maleic hydrazide exceeded that of the check at only the first harvest date, or 21 days after applications.

Two,4-D treatments significantly decreased the average sugar content, but had no significant effect on the total yield as compared to the untreated beets. The yield of beets treated with 2,4-D was higher than those treated with maleic hydrazide but it was not significantly higher than average yield of the checks.

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Some Effects of Preharvest Foliage Sprays of Maleic Hydrazide on the Sugar Content and Storage Losses of Sugar Beets[1]

S. H. WITTWER AND C. M. HANSEN[2]

Preliminary experiments (8)[3] have indicated that a preharvest foliage spray of 2,500 parts per million of maleic hydrazide reduces the loss of sucrose in sugar beets stored for processing. In these initial tests spray concentrations ranging from 500 to 5,000 parts per million applied at intervals between six weeks and 48 hours of harvest produced no noticeable effects on the plants growing in the field. Furthermore, the chemical, irrespective of dosage or time of application, did not influence yield or beet size or reduce the percentage of sucrose in the beets at harvest time. Sugar beets harvested from plants which had received a 150-200 gallon per acre spray application of 2,500 parts per million of maleic hydrazide two weeks or more before harvest and subsequently placed in storage held at various temperatures were noted to be free of sprout and root growth while control lots sprouted profusely.

Others have reported that maleic hydrazide exerts a controlling influence on carbohydrate metabolism and accumulation in several plants (1, 4, 5, 7). The recent paper by Naylor (6) interestingly provides data showing a 13-fold increase in the sucrose content of seedling maize tops following treatment with maleic hydrazide. Thus, it became of interest to investigate more thoroughly the possible effects this substance may have upon sucrose accumulation in the sugar beet, as well as possible reduction of losses of sucrose during storage.

Table 1.—The Effects of Preharvest Foliage Sprays of Maleic Hydrazide on the Sucrose Content of Sugar Beets.

Treatments		Percent Sucrose	
Spray	Storage	At Harvest	After 30 Days Storage
Maleic hydrazide as MH-30, Sept. 7	Not ventilated or washed	18.15	17.57
Maleic hydrazide as MH-X22, Sept. 20	Not ventilated or washed	17.89	17.21
Maleic hydrazide as MH-Na, Sept. 20	Not ventilated or washed	17.65	17.40
Maleic hydrazide as MH-30, Sept. 28	Not ventilated or washed	17.76	17.08
Control (no treatment)	Ventilated and washed	17.17	16.72
Control (no treatment)	Ventilated and not washed	16.79	16.44
Control (no treatment)	Not ventilated or washed	16.54	15.78
Least differences necessary for significance between treatments—	5% level	0.48	0.66
	1% level	0.64	0.88

[1] Journal Article 1,325 from the Michigan Agricultural Experiment Station.

[2] Professor of Horticulture and Assistant Professor of Agricultural Engineering, respectively, Michigan Agricultural Experiment Station.

[3] Numbers in parentheses refer to literature cited.

Experimental Procedure

One-acre randomized field plots of sugar beets, grown on a productive mineral soil, were sprayed at various dates prior to harvest with 2,500 parts per million of maleic hydrazide of several formulations[4] (Table 1). For each acre plot approximately 200 gallons of spray was applied at 300 pounds pressure, sufficient to wet the leaves to run-off. Triton B1956[5] was used as a wetting agent with the MH-30 formulation at the rate of one pint to 100 gallons of water. Beets were mechanically harvested and topped October 16 to 18. In agreement with previous studies (8), yield estimates showed no influence of any of the treatments on the tonnage of beets harvested.

Table 2.—Effects of Preharvest Foliage Sprays of Maleic Hydrazide on Storage Losses of Sugar Beets.

Treatments		Percent Loss of Original After 30 Days Storage		
Spray	Storage	Weight of Beets	Sucrose Content	Total Sucrose
Maleic hydrazide as MH-30, Sept. 7	Not ventilated or washed	11.7	3.2	14.6
Maleic hydrazide as MH-X22, Sept. 20	Not ventilated or washed	13.3	3.8	16.6
Maleic hydrazide as MH-Na, Sept. 20	Not ventilated or washed	7.9	1.4	9.2
Maleic hydrazide as MH-30, Sept. 28	Not ventilated or washed	10.9	3.8	14.3
Controls (no treatment)	Ventilated and washed	12.9	2.6	15.2
Controls (no treatment)	Ventilated and not washed	12.6	2.1	14.5
Controls (no treatment)	Not ventilated or washed	9.8	4.6	14.0

Approximately five tons of beets were sampled from each of the treated and control plots. After duplicate weighings they were placed in especially designed experimental bin storages in an open shed and subjected to the various storage treatments listed in Tables 1 and 2. The design of the bins with facilities and procedures for ventilation, in the bins which were ventilated, have been described by Hansen (3). As the bins were filled, 10 random selected beet samples for sucrose analyses were taken at six-inch depth intervals. On November 15 to 17, after 30 days of storage, when the bins were unloaded, care was again taken to select beets for sucrose analyses from the same levels and locations where the original samples were taken.

Comparative temperature patterns in each of the storage bins were obtained by means of copper constantan thermocouples and an eight-point electronic recording potentiometer (Brown), connected to a stepping switch arrangement so that 48 readings could be taken consecutively. Temperatures characteristic of the location of each thermocouple were recorded automatically at three-hour intervals. Each bin had 16 thermocouples placed in

[4] MH-30, a water soluble diethanolamine salt containing 30 percent maleic hydrazide. MH-X22, a water soluble diethanolamine salt of maleic hydrazide containing a wetting and sticking agent. MH-Na, the sodium salt of maleic hydrazide containing a wetting and sticking agent.

[5] Rohm and Haas, Philadelphia, Pa.

four layers 12 inches apart, starting 12 inches from the bottom. Two thermocouples in each layer were placed into the center of beets and the other two recorded the air temperatures in the interstices.

Beets for each bin were accurately weighed immediately before binning and again at the conclusion of the experiment. The total weight losses combined with the initial and final percentages of sucrose in the beets provided an accurate record of the storage losses of sugar.

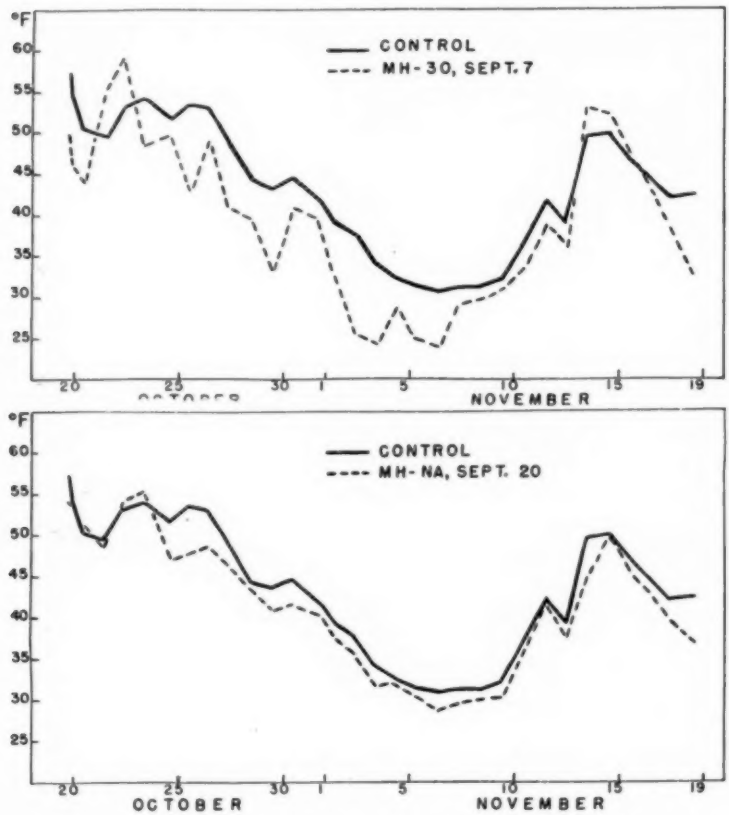

Figure 1. The effects of a preharvest foliage spray of maleic hydrazide (2,500 ppm.) on average daily storage bin temperatures of sugar beets. Top, comparison of bin temperatures of beets harvested from a non-treated (control) plot and one sprayed with the diethanolamine salt of maleic hydrazide on September 7; bottom, comparison of bin temperatures of beets harvested from a non-treated (control) plot and one sprayed with the sodium salt of maleic hydrazide on September 20.

Results

Sugar analyses (Table 1) following harvest suggest that maleic hydrazide applied as a preharvest foliage spray in the three formulations on the dates listed significantly increased the sucrose content of sugar beets. Differences in sucrose composition approach a 10 percent increase.

In Table 2, comparative net storage losses of sucrose resulting from the maleic hydrazide treatments and the various storage conditions are presented. Both loss in weight and changes (decreases) in sucrose composition of the beets are considered. Little significance can be attached to any of the differences with the possible exception of the sodium salt formulation (MH-Na) applied September 20. Beets harvested from plants sprayed with this chemical showed a considerable reduction in total sugar loss apparent in changes in both weight and composition during storage. The data for this particular treatment, as well as the records of the average daily temperatures prevailing in treated and control bins, are similar to results already reported (8).

Tabulations of average daily temperatures prevailing in each bin for the duration of the storage tests gave, in general, lower values for bins containing beets harvested from plots treated with maleic hydrazide. In these tests neither washing the beets nor ventilating the bins altered the temperatures. The comparative temperature patterns of the control (not ventilated or washed) bin, and those found in bins of beets harvested from plots treated with MH-30 on September 7, and the sodium salt or maleic hydrazide on September 20, are illustrated (Figure 1). A ten-day interval of continuous below freezing outdoor temperatures in early November followed by unseasonably high temperatures necessitated an untimely termination of the experiment and likely contributed to the nature of the results obtained in the storage tests.

The several experiments conducted to date concerned with the various effects of preharvest foliage sprays of maleic hydrazide on sucrose accumulation in sugar beets before harvest and the losses of sucrose in storage piles prior to processing, as well as possible influences on top-root ratios (2), suggest interesting possibilities and the need for further detailed investigations of the effects of this unique plant growth regulator on sugar beet metabolism.

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Two Years' Results Evaluating Effect of Preharvest Sprays of Maleic Hydrazide on Respiration and Spoilage of Sugar Beets

MYRON STOUT[1]

Introduction

Maleic hydrazide has recently received considerable attention as a plant growth regulator and herbicide (2, 3, 4)[2]. It has also been used as a preharvest spray for improving the storage of carrots and onions (6). Other reports have indicated it to be effective in reducing sugar losses in stored sugar beets (7, 8).

Sodium azide inhibits the action of several of the enzymes involved in plant respiration (1). Since maleic hydrazide is readily translocated within the plant (3, 4, 5) and is somewhat similar in chemical constitution to sodium azide, it might be expected to affect respiration by affecting some of the enzymes involved. Wittwer and Hansen (6, 7) observed that beets previously treated with maleic hydrazide and stored in a large bin were cooler than untreated beets stored in a similar bin, and suggested that the chemical may have inhibited respiration and thereby reduced the heat output of the treated beets.

Several sugar factories in the intermountain and northwestern part of the United States operate for periods of from five to six months. This long operating period requires that they start processing sugar beets before sugar percentage and purity values have attained a desirable level. Since maleic hydrazide has been reported to affect sugar metabolism in other plants (3, 4), it might be expected to affect sugar accumulation in sugar beets.

The studies here reported were designed to give some information on the possible effect of preharvest sprays of maleic hydrazide on sugar accumulation in the beet as well as its effects on reducing storage losses.

Experimental Results

The maleic hydrazide used in the following tests was applied as the diethanolamine salt formulation containing the equivalent of 30 percent maleic hydrazide. All spray concentrations reported are calculated to the equivalent concentration of maleic hydrazide. Maleic hydrazide was applied to sugar beets at two concentrations and at three dates before harvest in 1950. Each plot consisted of eight rows of beets 40 feet long. The spray was applied at the rate of about 82 gallons per acre (one gallon per plot) by means of a hand-operated tank sprayer. Twelve and six-tenths grams of Dreft per gallon of spray were added as a wetting agent. No rain fell for 48 hours after the first beets were sprayed September 1. A "trace" of rain fell 24 hours after the beets were sprayed September 12. Three one-hundredths inches of rain fell about 48 hours after the beets were sprayed September 15.

Six analytical samples of beets were harvested before the beets were sprayed September 1, 1950.

The beets were harvested, washed and samples selected for immediate analysis or respiration study September 18-19, 1950. Each sample consisted

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[2] Numbers in parentheses refer to literature cited.

Table 1.—Effect of Maleic Haydrazide on the Respiration Rate and Spoilage of Sugar Beets. Beets Grown in 1950 at Hill Brothers Farm.

Sprayed Date	Conc.	Beets per acre	Dry substance	Sugar	Purity	Invert	Respiration rate (at 72° F.) O_2 per Kg. per Hr.—Period: 1[1]	2[2]	3[2]	4[2]	Calculated losses during 27-day period at 72° F. Wt.	Sugar	Purity	Invert	Sugar by resp.
	P.P.M.	tons	%	%	%	%	mg	mg	mg	mg	%	%	%	%	%
					September 1, 1951										
Top check		25.1	14.61	12.45	85.24										
Bottom check		24.4	13.81	11.13	80.63										
					September 18, 1951										
Top check		27.0	14.95	12.78	85.48	.06									
Bottom check		26.6	13.73	11.14	81.14	.08									
Average		26.8	14.34	11.96	83.31	.07	15.61	14.14	16.12	20.49	1.95	1.65	10.50	.71	.82
9/1	1,000	27.9	15.00	12.72	84.80	.08	15.82	12.02	10.17	10.17	1.18	0.62	6.15	0.32	.69
9/1	2,500	27.5	15.11	12.63	83.59	.08	15.73	13.30	13.24	15.36	0.95	1.26	8.29	0.51	.77
9/12	1,000	26.0	13.44	11.21	83.41	.07	16.25	14.13	13.16	15.00	1.62	1.10	9.03	0.50	.82
9/12	2,500	29.9	13.07	10.51	80.41	.08	16.04	12.76	11.24	12.38	0.68	0.79	7.04	0.38	.74
9/15	2,500	29.2	13.82	11.24	81.33	.06	15.62	12.14	10.41	11.10	0.70	1.21	8.76	0.64	.70
9/15	5,000	28.4	13.47	10.92	81.07	.08	16.36	12.59	10.60	11.24	0.18	1.28	9.42	0.43	.73
Dipped															
9/18	2,500	26.8	13.34	11.96	83.31	.07	16.62	13.10	12.19	14.84	0.58	1.79	10.26	0.53	.76
Diff. for Sig. 5% point								2.94				1.00	5.00	0.44	.17

[1] = 5-day period.
[2] = 7-day periods.

of 13 beets weighing a total of 20 kg. or 44.1 pounds. Four samples per plot were analyzed and four samples were used in the respiration studies (2 samples per respiration chamber). The data in Table 1 show a gradient in sugar and purity from the top to the bottom of the field. This gradient is also shown in the check samples harvested September 1. The spray treatments in Table 1 are listed in consecutive order from the top to the bottom of the field. The gradients in sugar and purity values of the various spray treatments are well within the limits of error expected and indicate no real differences due to the application of the sprays. The respiration data in the central part of Table 1 show no significant differences between treatments during the second period of the test.

During the latter part of the test fungi developed in some of the respiration chambers, causing an appreciable increase in the measured respiration values. Fungi developed on three beets in one chamber of the "check" beets, causing a very high "respiration rate" toward the end of the test. The other chamber containing "check" beets was free of fungi and among the lowest in respiration rate. True respiration values can be expected only comparatively early in the test. Later values serve to indicate relative growth of fungi.

The loss in sugar of the beets sprayed September 1 at a concentration of 1,000 ppm. appears to be significantly lower than the check or those dipped in the maleic hydrazide solution before storage. The calculated F value, however, was 1.33 while that required for significance at the 5 percent level was 2.49. It is believed that the analytical loss of sugar is probably the least reliable measurement in determining total losses during storage. If the total of the calculated losses of sugar due to respiration and spoilage (inversion) are determined, they should be approximately equal to the losses of sugar as shown by analysis. The average losses of all treatments, when calculated by respiration and inversion, were 1.26 percent sugar. The average analytical losses were 1.21 percent sugar. The losses of sugar due to non-spoilage respiration required only 0.17 percent for significance, and that due to spoilage required a difference of 0.44 percent, while the analytical loss of sugar required 1.00 percent for significance. The respiration losses are probably the most reliable values in such a test because of greater freedom from analytical sampling errors.

A more highly replicated test was conducted in 1951. The plan, suggested by Dr. D. D. Mason, head of Biometric Services of this Bureau, consisted of two adjacent Latin squares (eight replications of four treatments). The plots were laid out in a selected commercial field of beets. Each plot consisted of two rows of beets 30 feet long. One buffer row was left between adjacent plots. A fresh lot of maleic hydrazide was secured and Triton B-1956 was used as the wetting agent. The spray was applied at the rate of 110 gallons per acre September 4, and no rain occurred before harvest September 17. Before harvest one beet was cut out and discarded between the ends of adjacent sections. The beets were uniformly topped, washed, sampled and placed in the respiration chambers September 18-19. Each sample for analysis or respiration study was selected to consist of 16 beets weighing a total of 18 kg.

The data in Table 2 show that there were no significant differences between treatments in beets per 100 feet of row, tons per acre, sugar or purity at harvest. There was no significant difference between treatments in respiration rate.

At the conclusion of the test all samples were reweighed, analyzed and the analyses calculated to the original weights of the samples. The calculated losses in Table 2 show there were no significant differences in sugar percentage, purity or increase in invert sugar during the 38-day period that the beets were stored in the respiration chambers.

Table 2.—Effect of Preharvest Sprays of Maleic Hydrazide on Yield and Quality of Beets at Harvest and Respiration and Spoilage Losses During Storage at 72° F. for 38 Days. Beets Grown in 1951 at Swenson Farm.

Spray concentrations	Yield beets per 100 feet	Tons per acre	Dry substance	Sugar	Purity	Invert	Residual M.H. in pulp
P.P.M.	No.	Tons	%	%	%	%	P.P.M.
Check	72.4	24.60	15.74	13.15	83.45	.11	0.0
1,250 ppm.	71.7	25.27	15.57	13.09	83.94	.11	3.0
2,500 ppm.	73.3	24.82	16.16	13.64	84.30	.12	6.7
5,000 ppm.	75.2	25.56	15.87	13.52	85.00	.11	12.8
Diff. for Sig.	4.0	2.53		1.05	1.97		

Spray concentrations	Respiration rate at 73° F. O_2 per Kg. per hour during period				Calculated losses during 38-day period at 72° F.			
	1[1]	2[2]	3[2]	4[2]	Sugar	Purity	Invert Increase	Sugar by resp.
	mg	mg	mg	mg	%	%	%	%
Check	12.86	10.73	9.65	10.30	.95	3.59	.248	.87
1,250 ppm.	12.78	11.13	10.20	10.88	.72	3.55	.223	.90
2,500 ppm.	13.47	11.01	10.26	11.26	1.43	6.22	.374	.89
5,000 ppm.	13.91	11.06	9.54	9.63	.74	4.43	.276	.90
Diff. for Sig 5% point		0.87			.92	3.05	.149	.07

[1] = 5-day period.
[2] = 10-day periods.

The calculated loss of sugar based on the respiration rates during the second period of the test required only 0.07 percent for statistical significance at the 5 percent point. The loss due to spoilage (increase in invert sugar) required only .149 for significance. The sum of the losses by respiration and spoilage probably is more nearly accurate than the loss of sugar by direct analysis due to the greater variation between samples in sugar content.

Discussion

The fact that preharvest sprays of maleic hydrazide failed to cause any observable effects on sugar beets in the 1950 tests might be explained on the basis that the amount which reached the storage tissues was inadequate to be effective. However, the beets which were dipped in a solution containing 2,500 ppm. of maleic hydrazide were affected to the extent that all subsequent growth of leaves turned dark in color and apparently died after growing less than one-half inch. The amount of regrowth of leaves on the beets given other or no treatment was not large or sufficiently different to be noticeable.

The untreated beets in the 1951 test were thought to have a little more regrowth on them than those sprayed with maleic hydrazide. The amount of regrowth was small, however, and further observations of samples of all lots stored for more than 110 days in the root cellar failed to show any appreciable regrowth or consistent differences between treatments. The gradation of the amounts of residual maleic hydrazide found in the tissues of beets which received different concentrations of spray indicated that there should have been some response to the chemical if it had any appreciable effect on storage.

Although sampling errors were relatively large for loss of sugar as determined by direct chemical analysis, the loss of sugar as calculated from respiration rates was very much less variable. The difference necessary for statistical significance as calculated from respiration rates amounted to only 0.07 percent sugar. This lower variation between samples in respiration rate measurements may be due to several factors. Previous studies (5) have shown that soil fertility affects respiration rate only to a minor extent, but affects sugar percent and purity much more. The whole beet was used in samples for respiration rate while only the small section cut by the rasp was used for sugar analysis. Sampling after storage is subject to even greater errors because of the irregular occurrence of spoilage. The adoption of the multiple saw sampling technique would probably reduce sampling errors on stored beets.

There was no evidence in the present tests that maleic hydrazide affected sugar accumulation. If the chemical stopped foliar growth or reduced foliar or root respiration it should result in increased sugar accumulation. However, Currier et al (3) cited considerable evidence that maleic hydrazide prevents carbohydrate translocation in plants. Such an effect would prevent sugar accumulation in the root rather than increase it.

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Effects of Preharvest Sprays of Maleic Hydrazide on Sugar Beets

F. H. Peto[1], W. G. Smith[2] and F. R. Low[3]

A study of 20 years results from the Canadian Sugar Factories at Raymond, Alberta, (1)[4] shows that killing frosts occurring prior to harvest almost invariably cause a drop in sugar in the root. Sugar losses are most severe when rapid regrowth of tops occurs after freezing. Wittwer and Hansen (2) checked regrowth of tops in pile storage and reduced sugar losses by preharvest applications of maleic hydrazide.

Preliminary small scale experiments conducted at Vancouver, B. C., were designed to determine whether foliar sprays of maleic hydrazide prior to freezing would check regrowth of leaves after freezing and thereby conserve sugar. Controlled freezing in the field was achieved by the use of dry ice in an insulated box which was placed over the plants. A large scale field experiment was conducted at Taber, Alberta, to study the effects of preharvest sprays of maleic hydrazide on yield and sugar content at harvest, and the sugar and weight shrink during a storage period of 34 days.

Materials and Methods for Preliminary Experiments

A Naugatuck formulation of maleic hydrazide (M. H.) of 30 percent concentration was used in all of the experiments. This was diluted to one part per 100 and applied at approximately 50 gallons per acre.

Experiment 1.

In order to study the effects of midsummer M.H. treatments, beets were planted in the greenhouse March 20 and transplanted to the field in early May at Vancouver with beets spaced 8 inches apart. Each plot was limited to four beets to facilitate freezing in the field. There were four treatments replicated seven times as follows: 1. check, 2. M. H., 3. M. H. + Freeze, 4. Freeze. The M. H. was applied July 30 and the tops were frozen off August 16. The method of freezing consisted of covering four beets in the field with an insulated box 40 x 14 x 16 inches. Wire mesh trays containing about 60 pounds of dry (CO_2) ice were placed on a rack in the upper portion of the box. A 15-minute treatment period with such an apparatus was used to destroy the tops without noticeable damage to the crown.

The beets were harvested September 4. The tops, including the crowns, were weighed separately from the roots and the sugar content of the latter was determined.

Experiment 2

The same four treatments were used in this instance as in Experiment 1, but this experiment differed mainly in the fact that both planting and treatment were six weeks later, although the beets were approximately the same size at time of treatment. Another minor difference was the reduction in the number of replicates from seven to six. The M. H. treatments were applied September 18, and freezing treatments October 2 and the experiment was harvested October 18.

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[4] Numbers in parentheses refer to literature cited.

Table 1.—The Effect of Maleic Hydrazide Without Frost.

Experiment	Date of Treatment M.H.	Freeze	Interval Between M.H. Treatments and Harvest	Date of Harvest	Percent Sugar Ck.	M.H.	% Change	Ave. Root Wt. Gms. Ck.	M.H.	% Change	Ave. Top Wt. Gms. Ck.	M.H.	% Change
1	July 30		36 days	Sep. 4	13.43	15.14	+12.6[1]	195	139	—28.7	178	97	—45.5[1]
2	Sep. 18		30 days	Oct. 18	14.0	14.5	+ 3.5	163	178	+ 9.2	298	273	— 8.4
3	Oct. 2		15 days	Oct. 17	13.6	13.9	+ 2.2	174	160	— 8.0	343	313	— 8.7
3	Oct. 2		22 days	Oct. 24	14.2	14.7	+ 3.5	162	198	+22.2	295	309	+ 4.7
3	Oct. 2		29 days	Oct. 31	15.3	15.2	— 0.6	177	159	—10.2	272	242	—11.0

Effect of Freezing Without Maleic Hydrazide

					Percent Sugar Ck.	Freeze	% Change	Ave. Root Wt. Gms. Ck.	Freeze	% Change	Ave. Top Wt. Gms. Ck.	Freeze	% Change
1		Aug. 16	—	Sep. 4	13.43	12.0	—10.6[1]	195	138	—29.2	178	53.7	—69.9[1]
2		Oct. 2	—	Oct. 18	14.0	11.7	—16.4[1]	163	156	— 4.3	298	220	—26.2

Effect of Freezing on Maleic Hydrazide Treated Plots

					Percent Sugar M.H.	M.H.+Fr.	% Change	Ave. Root Wt. Gms. M.H.	M.H.+Fr.	% Change	Ave. Top Wt. Gms. M.H.	M.H.+Fr.	% Change
1	July 30	Aug. 16	36 days	Sep. 4	15.14	12.72	—16.0[1]	139	130	— 6.5	97	41	—57.7[1]
2	Sep. 18	Oct. 2	30 days	Oct. 18	14.5	12.6	—13.1[1]	178	163	— 8.4	273	231	—15.4

Effect of Maleic Hydrazide Treatments Prior to Freezing Tops

					Percent Sugar Freeze	M.H.+Fr.	% Change	Ave. Root Wt. Gms. Freeze	M.H.+Fr.	% Change	Ave. Top Wt. Gms. Freeze	M.H.+Fr.	% Change
1	July 30	Aug. 16	36 days	Sep. 4	12.0	12.73	+ 6.1[1]	138	130	— 5.8	53.7	41.0	—23.6
2	Sep. 18	Oct. 2	30 days	Oct. 18	11.70	12.60	+ 7.7[1]	156	163	+ 4.5	220	231	+ 5.0

[1] Difference significant to the 5% point

A comparison of Experiments 1 and 2 should give some indications of the influence of rate of growth on the effectiveness of M. H. treatments, since the growth rate would be much more rapid on July 30 than September 18.

Experiment 3

The objective in this experiment was to compare 2-, 3- and 4-week intervals between M. H. treatment and harvest.

Six plots were sprayed with M.H. and these were randomized with six check plots. The treatment was applied October 2 and on each of the harvest dates four beets were harvested from each treated and check plot.

Discussion of Preliminary Experiments

The data from three preliminary experiments have been consolidated in Table 1.

Effect of Maleic Hydrazide Without Frost

The results demonstrate that the July 30 application of M. H. checked root and top development and increased the sugar content to a much greater extent than did the September 18 and October 2 treatments. It appears likely that environmental conditions favoring rapid growth are those which result in maximum response to M. H. There would not be an economic advantage from the early treatments since the increase in sugar content did not compensate for the loss of weight.

In Experiment 3, there was no significant difference between the M. H. treatment and check in regard to percent sugar, root weight or top weight. Therefore, no conclusions can be drawn from effect of the interval between treatment and harvest.

Effect of Freezing Without Maleic Hydrazide

Freezing caused large and significant losses in sugar content of the root in both experiments. The late frost of October 2 caused larger losses in percent sugar than the early frost. The reduction in top weight was particularly striking in Experiment 1, but less so in Experiment 2 when the beet leaves would naturally be more frost-resistant. Reduction in root weight from frost was proportionally less than top weight in both experiments, and although the earlier frost treatment caused greater root weight reductions than the latter, the diffffferences were not statistically significant because of wide variability in root size in a four-beet sample.

Freezing in the field with dry ice is a very promising experimental method, but the size of the freezing box or the number of replicates must be increased to yield significant differences in weight of roots and tops.

Effect of Freezing on Maleic Hydrazide-treated Plots

Freezing caused large and significant losses of sugar in M. H.-treated plants in both Experiments 1 and 2. The freezing also caused a significant reduction in top weight in Experiment 1. There was a very small and insignificant reduction in root weight from the freezing.

Effect of Maleic Hydrazide Treatments Prior to Freezing Tops

The main objective of these particular treatments was to determine whether the serious losses in sugar resulting from freezing could be reduced by application of M. H. prior to freezing.

M. H. applications prior to freezing increased significantly the sugar content by 0.73 and 0.9 percent above the frozen plots. In experiments 1 and 2 freezing without M. H. caused reductions in sugar content of 1.43 and 2.3 percent respectively. M. H. treatments prior to freezing in the same experiments reduced these losses to 0.7 and 1.4 percent respectively. Thus, the average losses from frost were reduced 46 percent by M. H. treatments prior to freezing.

The M. H. applications prior to freezing had no apparent effect on root weight, but they reduced the amount of top regrowth in Experiment 1. In Experiment 2, there was no indication of reduction of top regrowth, but the M. H. treatment nevertheless conserved sugar.

Table 2.—Maleic Hydrazide Field Experiment, Taber.

Date Sampled		Acre Yield Sugar Lbs.	Acre Yield Beets Tons	Percent Sugar	Purity	Beets per 100 ft row
Oct. 5	Check	3,562	12.78	14.04	85.67	92
	Treated	3,578	13.00	13.82	85.20	87
	Diff.	16	.22	.22	.47	
	L.S.D.	426	1.97	.71	1.93	
Oct. 16	Check	3,526	12.19	14.58	84.44	88
	Treated	3,580	12.02	15.00	84.64	87
	Diff.	54	.17	.42	.20	
	L.S.D.	450	.63	.80	.90	
Nov. 2	Check	3,661	13.89	13.20	83.64	88
	Treated	3,494	13.37	13.14	83.26	93
	Diff.	167	.52	.06	.38	
	L.S.D.	450	1.93	.63	.90	

Field Experiment, Taber

This was a field scale experiment conducted at Taber, Alberta, on commercial beets. Four strips of one-half acre each were treated September 22, 1951 with approximately 50 gallons per acre of one part per 100 of M. H. 30. These strips were alternated with check strips of equal size. One-half inch of snow fell between 14 and 21 hours after treatment. Night frosts and light snow were reported September 24-27, with a minimum temperature of 26° F. on the latter date. The beets recovered from these early frosts and made slight growth in early October, but severe weather was encountered again on October 15 with 15 inches of snow between October 15 and 21 with minimum temperatures as low as 10° F. which, of course, largely destroyed the tops and damaged many of the crowns to a depth of two inches. Intermittent heavy frosts with occasional snow storms continued until the beets were dug and placed in storage November 12 and 13. Although the beets were not frozen on being placed in storage, about 90 percent showed discoloration for a depth of two inches in the crown and would normally be considered unsuitable for storage. About ten percent of the beets appeared frost-resistant.

Preharvest samples were taken October 5, October 16 and November 2 from the treated and check plots. A single sample consisted of the beets harvested from 50 feet of row, 20 samples were harvested on each date, 10 from each of the treated and untreated plots. The yield and sugar content were determined on each sample.

The remainder of the experiment was harvested and placed in bin storage November 12 and 13. The beets were stored to a depth of 90 inches in bins 8 x 10 feet. A sample of 20 beets was taken from each 10-inch level from both the treatment and check bins on filling the storage bins and similar samples were taken on removal from storage December 17. The storage temperatures at the center of each pile were recorded throughout the storage period with a two-pen recording thermometer.

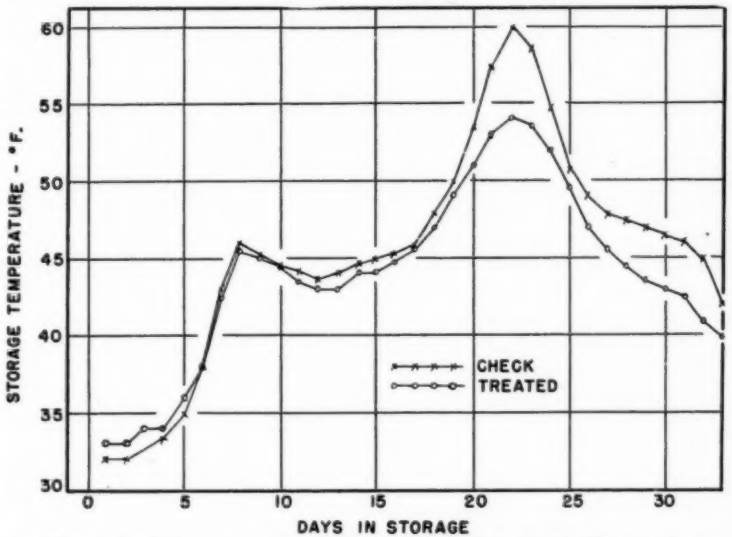

Figure 1. Effect of preharvest spray of maleic hydrazide on storage temperatures.

The beets from the check and treatment plots were weighed before and after storage, but the mud tare present under such difficult harvest conditions probably reduced the accuracy of the weight and total sugar data.

Discussion of the Taber Field Experiment

The field treatments of maleic hydrazide were applied September 22 and the results from the samples harvested on October 5, 16 and November 2 are shown in Table 2. The treatment had no apparent effect on tonnage, percent sugar or purity. While intermittent frosts and snow subsequent to treatment may have reduced the effectiveness of the treatment, nevertheless, the results are in agreement with preliminary experiment 3 conducted at

Vancouver under more favorable conditions and with those obtained by Wittwer and Hansen.

The temperatures recorded during the storage period are plotted in Figure 1. There was very little difference betwen the treatment and check temperatures for the first 17 days of storage, but during the remainder of the storage period, the treated beets remained consistently cooler. During this period, the temperature differences were similar to those obtained by Wittwer and Hansen and indicate that the M. H. may have had a depressing effect on the respiration rate.

On removal from storage, approximately one-third of the beets in each bin was partially rotted. This condition was worse in the crowns and in some cases it extended to a depth of two inches below the crown. There was very little regrowth during storage, and there were no observable differences between treatment and check in this regard.

A summary of the data obtained from the storage experiment is shown in Table 3. The treated beets contained 0.25 percent more sugar than the check at the commencement of storage and 0.38 percent more at the completion of storage. The latter difference was not statistically significant. The treated beets lost slightly less sugar during storage than the untreated beets, but again the small difference of only 0.13 percent was not significant.

Table 3.—Storage Test, Tabor

	Untreated	Treated
Sugar Content (Mean of 9 samples)		
Initial	13.11%	13.36%
Final	12.42%	12.80%
Loss during storage	.69%	.56%
Purity (mean of 9 samples)		
Initial	83.17%	83.27%
Final	81.43%	82.00%
Loss during storage	1.74%	1.27%
Weight		
Initial	21,599 lbs.	20,711 lbs.
Final	19,349 lbs.	18,701 lbs.
Shrink during storage	2,250 lbs.	2,010 lbs.
Shrink during storage	10.42%	9.71%
Total Sugar		
Initial	2,832 lbs.	2,767 lbs.
Final	2,403 lbs.	2,394 lbs.
Loss during storage	429 lbs.	373 lbs.
Loss during storage	15.15%	13.48%

At the completion of the storage period, there were slight differences in favor of the treated lot with regard to purity, shrink in weight during storage and loss of total sugar in storage. All the differences recorded in Table 3 show a trend in favor of the treatment and, while they are not statistically significant, they are sufficiently encouraging to justify further and more extensive experiments with maleic hydrazide.

Summary

In preliminary experiments, mid-summer foliage spraying of sugar beets with maleic hydrazide increased significantly the sugar content above the

untreated, but severely checked plant growth. Later treatments had no significant effects on either sugar content or root weight.

Freezing of beets caused severe reductions in sugar content.

The average losses in sugar content through frost damage were reduced 46 percent by M. H. applications prior to freezing.

M. H. treatments applied September 22 with a power sprayer to four strips of commercial beets at Taber, Alberta, failed to alter significantly either the sugar content or yield from sample plots harvested October 5, 16 and November 2.

Ten ton lots of treated and untreated beets with a heavy dirt tare were held in storage bins for 34 days. For the first 17 days of storage, the temperatures in the two lots were very similar. Subsequently, the temperature in the check bin rose to a maximum of 6° F. above the treated bin. The treatment exceeded the check by 0.25 percent sugar at the beginning of storage and 0.38 percent at the termination of storage, but these differences were not statistically signifificant.

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Effect of Frost on Sugar Content in Beets

F. H. PETO[1]

The very severe frost conditions encountered during the autumn of 1951 in the sugar beet growing areas of southern Alberta encouraged the re-examination of the sugar content of beets as related to frost injury during the first 30 days of the factory operations. The sugar content after 30 days of operation was not taken into account in order not to complicate the situation by introducing unknown storage losses. It was considered that 6° F. would cause killing of most of the tops and do some crown injury. A study was made of the sugar contents of the Raymond factory slice for 5- and 10-day periods before and after the campaign day on which the temperature fell to at least 26° F.

Table 1.—The Effect of a Killing Frost of 26° F. or Lower on Sugar Content in Beets, Data from Raymond Factory.

Year	Campaign Day of First 26° Frost	Change in Percent Sugar Immediately Before Frost		Change in Percent Sugar Immediately After Frost		Remarks
		5 day Period	10 day Period	5 day Period	10 day Period	
1932	16	+0.8	+1.6	—0.1	—1.1	
1933	24	+0.2	+0.7	—0.2	—	
1934	1	—	—	—0.1	—0.2	
1935	13	+0.4	+1.2	—0.2	—0.2	
1936	23	0	+1.4	—0.7	—	
1937	8	—0.2	—	0	0	Rain and Cloudy
1938	24	—0.1	0	+0.2	—	weather before fr.
1939	10	+0.4	—	—0.1	—0.5	
1940	0	—	—	—	—	
1941	30	+0.5	+0.4	—	—	
1942	30	+0.1	+0.2	—	—	
1943	29	—0.7	0	—	—	
1944	5	—	—	—0.4	—0.2	
1945	19	0	+0.9	—0.3	—0.1	
1946	9	—0.7	—	—0.3	—0.2	Rain preceded fr.
1947	23	+1.0	+1.7	—0.7	—	
1948	7	—0.2	—	+0.2	+0.5	Only 1 night of
1949	(Pre-crop Sep. 12)	—	—	—	—	killing frost.
1950	1	—	—	—1.0	—1.1	
1951	11	—0.1	+0.5	+0.5	+0.5	Below freezing for 12 days after first frost.
Ave.		+0.09	+0.78	—0.21	—0.24	

Table 1 shows that the sugar content of the beets sliced tends to rise until the campaign day with a 26° frost or lower. Subsequent to the first frost, regardless of its intensity below 26° F., the sugar content was usually decreased as a result of frost. This decrease showed up quickly within five days and is therefore not associated with obvious regrowth in such a short period. It appears that frost initiates certain biochemical changes in the root which result in loss of sugar. There was evidence from the 1951 data that the sucrose content did not decrease as long as the beets remained

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frozen or close to freezing as they did for 12 consecutive days in 1951. By contrast in 1950, a frost occurred on the first crop-day and the weather warmed up right afterward. This condition caused a serious reduction in sugar content as shown in Table 1.

Further evidence on the effect of frost on the sugar content of beets is illustrated in Figure 2. The average of 20 years' results for the sugar content of the Raymond Factory slice shows that there is a rapid rise in sugar of .78 percent in the 10-day period preceding the frost and a fall of 0.24 percent within 10 days subsequent to frost.

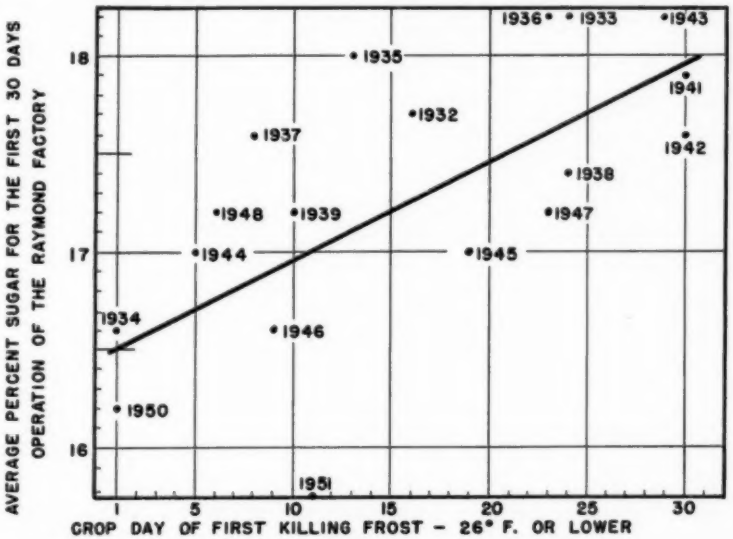

Figure 1.—Relation of Sugar Content to First Killing Frost.

A study of Raymond operations indicated that the date of occurrence of the first killing frost might have a causal relationship with the average sugar content of the crops. Again the 30th crop-day was selected as indicating the true sugar content of the crop without complications of storage losses. Figure 1 shows a relationship between the average percent sugar for the first 30 days plotted against the crop-day when the first killing frost of 26° F. or lower occurred.

It was necessary to eliminate 1940 and 1949 from this data. Nineteen hundred forty was eliminated because no frost occurred during the period and 1949 was eliminated because the first killing frost occurred on September 12. We are convinced that this very early frost was responsible for the abnormally low average sugar content of only 14.5 percent at the 30-day point. However, its effects could not be conveniently correlated with frosts occurring after the commencement of harvest.

The slope of the regression was calculated and is shown in Figure 1. A positive significant correlation of +0.64 was calculated from these data.

Discussion

It has long been recognized that a number of factors influenced sugar content in beets at harvest, e.g.

1. Variety (sugar, normal or tonnage types).
2. Length of growing season.
3. Soil and fertility factors.
4. Climate—Rainfall.
   Temperature (frost)
   Sunlight

Regrowth after a killing frost has been well known to reduce sugar content. This effect was particularly noticeable when a killing frost occurred in 1949 on September 12. However, it has not been widely recognized

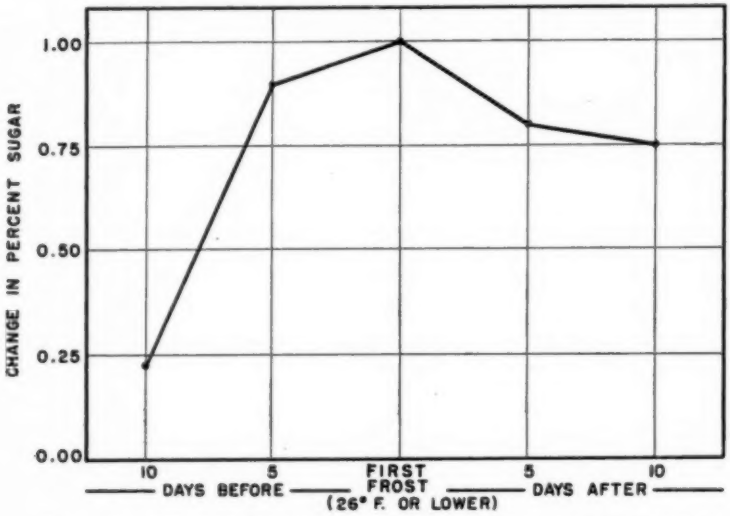

Figure 2.—Effect of Frost on Sugar Content. Average of 20 Years' Results at Raymond.

that practically all killing frosts are followed rapidly by a reduction in sucrose content in the root. One might assume that any inversion of sucrose would be accompanied by a noticeable rise in invert sugars. It may be that inverts are formed but are intermediate and transitory in katabolism. It might also be assumed that any rapid loss of sugar might be accompanied by an increased respiration rate. The plain truth is that there is a serious

deficiency of knowledge on the biochemical reactions associated with the thawing of sugar beets.

The positive correlation which exists between the sugar content of the crop as measured by sugar to date at the 30-day point in the campaign and the date of the first killing frost suggests that frost immediately preceding or during harvest dominates all the other factors which could be involved. Thus, this indicates the importance of frost resistance in sugar production in Alberta.

Marked varietal differences in frost resistance were noted last autumn in Alberta. For example, a high-sugar Polish Variety, Udycz A, appeared to have a much higher degree of resistance than most other varieties. However, in our own stock there is considerable variation in frost resistance so that it ought to be possible to breed specifically for this character.

If sugar losses are associated with freezing of beets in the field, then the likelihood exists that serious losses of sugar in pile storage could result from recurrent freezing and thawing, even though there was no obvious rotting of the root tissue.

Since it is apparent that frost damage is a dominant factor in limiting the sugar producing capacity in many northerly beet producing areas, research programs in these regions should include investigations along the following lines.

1. Biochemical studies to determine what happens to the sugars in beets on freezing and thawing.

2. Respiration studies on beets recovering from frost as compared to unfrozen beets.

3. Further studies on maleic hydrazide and related hormones to determine their efficiency in reducing sugar losses following freezing or in storage without frost.

4. Breeding and selection for frost resistance.

Induction of Reproductive Development in Sugar Beets by Photothermal Treatment of Young Seedlings[1]

JOHN O. GASKILL[2]

In many types of breeding jobs and genetic studies with sugar beets, *Beta vulgaris* L., a short life cycle is very desirable, provided it does not promote the development of annual genetic tendencies. Various techniques have been employed for that purpose by breeders in the United States.

One of the most efficient of these methods, from the standpoint of time required for the complete cycle, was developed a number of years ago by the Division of Sugar Plant Investigations[3]. Seed is planted in the greenhouse in the fall, and the young seedlings are photothermally induced (in the greenhouse) by prolonged cool temperature and continuous light. The induction process[4], with average temperature of approximately 50° F., requires about two and one-half to three months, and the seed crop may be harvested within six to seven months from date of planting.

The method has proved satisfactory through experience at Fort Collins, Colorado; Beltsville, Maryland, and Salt Lake City, Utah, but its usefulness is limited by its dependence upon cold weather for induction.

As a result of a series of experiments conducted recently at Fort Collins, a new method has been developed by means of which two successive generations of sugar-beet seed can be produced in 12 months. Seed yields are relatively small. However, in breeding work and genetic studies a short life cycle frequently is far more important than a large quantity of seed per plant. Although further research undoubtedly will lead to improvements in technique and to a clearer understanding of the usefulness and limitations of this method, results obtained thus far have shown quite conclusively that it is practicable under conditions existing at Fort Collins.

A brief, tentative outline of the method has been presented in another report (1)[5], and it is the purpose of this paper to summarize the experimental results.

Experimental Procedure and Results

A preliminary experiment, begun in the fall of 1950, showed that induction can be accomplished satisfactorily in young sugar beet seedlings in the absence of sunlight by means of prolonged exposure to low temperature with continuous artificial light.

In subsequent experiments discussed in this paper all induction treatments were performed in that way, with light provided by means of one 150-watt, white-frosted, incandescent electric bulb in a medium depth reflector, 14 to 16 inches in diameter, suspended 20 inches above the sur-

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[1] Report of experimental work conducted by the Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, in cooperation with the Botany and Plant Pathology Section, Colorado Agricultural Experiment Station, Colorado A & M College, and approved by the Station for publication as Scientific Series Article No. 379.

[2] Plant Pathologist, Division of Sugar Plant Investigations. Acknowledgment is made to Myron Stout, Plant Physiologist, for suggestions regarding certain phases of these studies, to Joseph A. Elder, Agricultural Aid, for assistance in carrying out the experimental procedures, and to J. L. Fults, Botanist, Colorado Agricultural Experiment Station, for helpful advice.

[3] Unpublished results of experiments conducted by F. V. Owen, Dewey Stewart, and John O. Gaskill.

[4] The physiological and other changes required to shift the plant from the vegetative to the reproductive phase.

[5] Numbers in parentheses refer to literature cited.

face of the soil. In cases where "continuous" illumination is referred to in connection with field and greenhouse conditions, sunlight was supplemented by means of the same type of incandescent unit, operated throughout each night, with the reflector about 30 inches above the soil at first and raised as seed stalks elongated. More than one light unit was used only for especially large groups of pots. Temperatures in greenhouse and field were recorded in the shade by means of thermographs. Thermometers were used for this purpose in the induction room with bulbs directly beneath the light, about one-half inch above the surface of the soil, and not shaded.

Age of Seedlings

An experiment, designated as number two, was designed primarily to study the effect of age of seedlings on reproductive response to photothermal treatment. The wide-base, leaf-spot-resistant variety, U. S. 226, about average in bolting[6] tendencies, was chosen for this study. Seed was planted on four different dates in three-inch pots which were kept in a warm greenhouse with continuous light until March 9, 1951, when they were transferred to the induction room. Seedlings were thinned at random to two per pot not long after appearance of the first pair of true leaves on the majority of plants of any given age group. After 6 to 10 weeks' induction treatment at approximately 48° F., the plants in each pot were transferred to a six-inch pot and returned to moderately warm greenhouse conditions where continuous light was provided. The seed was harvested and final counts were made 13 weeks after the end of induction exposure.

The principal highlight in the summarized results of experiment 2 (Table 1) is in the relationship between seed yields and ages of plants at the beginning of induction—a strong trend toward higher yields for older plants. This trend is illustrated in Figure 1 which also shows a tendency for older seedlings to bolt and reach flowering stage more promptly.

From these results it was concluded that, for most practical purposes, seedlings should be allowed at least to emerge from the soil before being subjected to induction treatment. In this experiment, emergence in the greenhouse occurred largely between the fifth and tenth days after planting; none before the fifth day. A second highlight which may be noted in Table 1 is that 38 of the 40 plants receiving 10 weeks' induction exposure (series "C") developed seed balls by date of harvest—23 to 27 weeks after the seed had been planted. Germination for the four treatment numbers ranged from 75 to 90 percent. Average weekly temperatures (°F.), as determined from hourly readings on thermograph charts, for the first 6 weeks of the post-induction period for series "C" were 68, 67, 65, 64, 68 and 66 respectively; average 66. Determined from the same charts, the average daily maximum for the 6-weeks' period was 84°; and the average daily minimum was 54°.

From the seed-stalk counts given in Table 1 it is apparent that induction exposure of 8 weeks or less was insufficient to produce satisfactory bolting under the conditions of the post-induction period. However, it should be noted that the 3 groups of plants, representing the 3 lengths of induction, were returned to the greenhouse on different dates. Consequently they

[6] Seed-stalk production.

were not under identical conditions of light and temperature immediately following induction and therefore were not strictly comparable.

Induction Time and Temperature

Experiment 3 was conducted for the purpose of studying effects of induction time and temperature, using a seed lot which had been produced by means of a representative mass increase of the backcross, multigerm x (multigerm x monogerm). The population dealt with was known to include a substantial proportion of slow-bolting individuals requiring more than the average length of induction treatment for satisfactory bolting—a characteristic inherited from the monogerm parent (2).

Seedlings were grown for two weeks in three-inch pots in a warm greenhouse, thinned to four plants per pot, and then subjected to the following induction treatments:

Table 1.—Reproductive Response of Sugar-beet Seedlings of Different Ages to Photothermal Induction Treatments; U. S. 226 Variety.

Treatment No.	Pre-induction period in greenhouse[1]	Induction period[2]	Harvest results[3]				
			Total plants living	Plants with normal seed stalks[4]	Plants having well-formed seed balls	Average wt. of seed per plant[5]	Germination[5]
	Days	Weeks	Number	Number	Number	Grams	Percent
1A	0	6	10	8	7	1.4	67
2A	4	6	10	5	5	1.1	69
3A	14	6	10	8	8	2.8	80
4A	28	6	10	8	8	2.8	74
1B	0	8	10	5	4	0.6	43
2B	4	8	8	7	5	2.6	87
3B	14	8	10	9	7	4.2	89
4B	28	8	10	8	8	4.8	91
1C	0	10	10	10	9	1.0	75
2C	4	10	10	10	10	1.5	88
3C	14	10	10	9	9	2.3	90
4C	28	10	10	10	10	5.0	85

[1] Time computed from date of seeding until beginning of induction period.
[2] Induction period (low temperature and continuous artificial light) began on March 9, 1951, for all treatment numbers.
[3] Seed harvested and final counts made 13 weeks after end of induction exposure.
[4] Vegetative type seed stalks (classed as abnormal) were excluded.
[5] Based on plants having well-formed seed balls, only.

Three groups of plants were held for five weeks at temperatures of approximately 40°, 48°, and 57° F., respectively. Another set of three groups was given 10 weeks' exposure in a similar manner. Plantings were so timed that induction treatments for all six groups ended on July 27, 1951. On that date the four seedlings in each pot were transplanted in an eight-inch pot and taken to the field together with a set of comparable controls which were four weeks old at that time. Since days were rather long when this experiment was begun, no direct artificial light was given to the controls before July 27 or to the other plants prior to induction treatment. However, as a precaution against reversal, continuous light was provided as usual during the post-induction period. The plants remained in the field under a lath shelter (partial shade) from July 27 until September 12, and then were returned to the relatively warm greenhouse. Average field temperatures (°F.) during the first six weeks following July 27 were 72, 67, 66, 62, 65 and 65, respectively; average for the 6-weeks' period, 66. The average daily maximum was 78, and the average daily minimum was 56.

The results (Table 2 and Figure 2) show that five weeks' induction treatment was decidedly inadequate at each temperature. Ten weeks' induction produced better results at each temperature—strikingly so in the case of treatments four and five—as judged by final percentages of normal seed stalks.

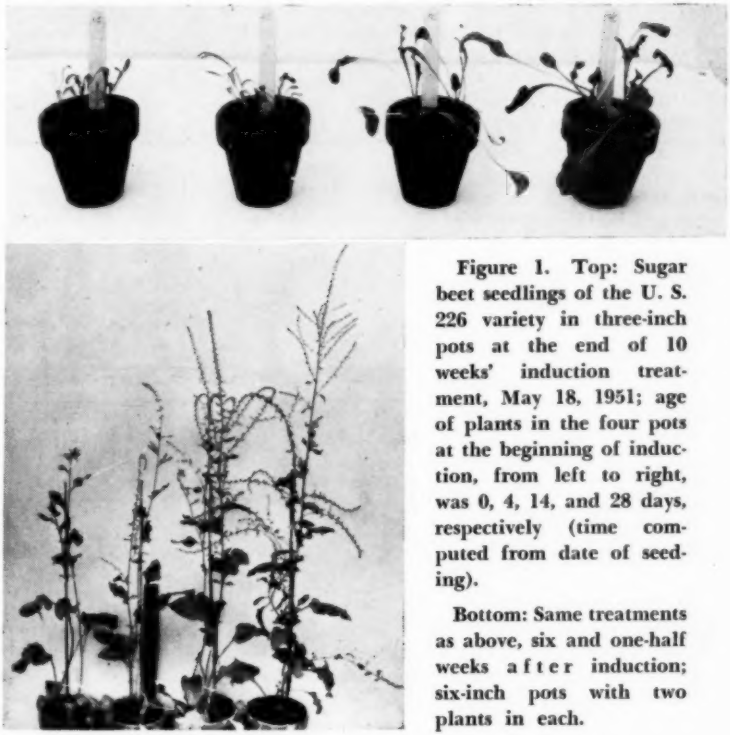

Figure 1. Top: Sugar beet seedlings of the U. S. 226 variety in three-inch pots at the end of 10 weeks' induction treatment, May 18, 1951; age of plants in the four pots at the beginning of induction, from left to right, was 0, 4, 14, and 28 days, respectively (time computed from date of seeding).

Bottom: Same treatments as above, six and one-half weeks after induction; six-inch pots with two plants in each.

Considering these final figures, together with counts made earlier, it appears that, under conditions such as those maintained in this experiment, the optimum temperature for induction of young seedlings of the type used in this study is about or possibly a little below 48° F. It is of interest to note that this conclusion approximates that reported by Stout (3) for induction of sugar-beet roots stored in the dark.

In actual practice, normal seed-stalk production closely approaching 100 percent usually is desirable. Although the best treatment in this experiment (No. 5—intermediate induction temperature for 10 weeks) resulted in only 86 percent normal bolting, it should be noted in the results reported for experiment four that 11 weeks' induction produced nearly 100 percent normal bolting in plants of the same strain (Table 3).

Supplemental Light in the Post-Induction Period

When fully induced sugar-beet roots (mother beets or stecklings) are used for growing seed in the usual way, with transplanting in the field taking place fairly early in the spring, artificial light is not necessary. However, it was suspected that small seedlings might require supplemental light in the post-induction period, especially when that period begins in warm weather. In order to study the importance of extra light at that time, a simple comparison was made between two sets of plants. For convenience this will be called experiment 4.

Table 2.—Results of a Time and Temperature Study Pertaining to Photothermal Induction of Young Sugar-beet Seedlings of a Relatively Slow-bolting Strain; 28 Plants in Each of 7 treatments.

Treatment No.	Induction treatment		Early counts—total[1] plants with seed stalks		Final counts—plants with normal seed stalks[2]	
	Weeks	Average temperature	1 week	2 weeks	Total	Flowering
	Number	°F.	Percent	Percent	Percent	Percent
1	5	40	0	0	21	14
2	5	48	0	4	18	18
3	5	57	11	14	22[3]	22[3]
4	10	40	7	54	71[4]	68
5	10	48	50	71	86[4]	79
6	10	57	4	29	36[4]	32
7	0	(Control)	0	0	4	4

[1] All plants with seed stalks large enough to detect, one week and two weeks after the end of induction treatment.
[2] Counts made 10 weeks after end of induction period; vegetative type seed stalks (classed as abnormal) were excluded.
[3] Based on 27 living plants.
[4] Analysis of variance, performed for treatments 4, 5, and 6, only, showed that 4 and 5 did not differ significantly in percentage of plants with normal seed stalks, but each was significantly superior to number 6.

Seedlings of the same strain as that used in experiment three were grown in flats for 13 weeks—the first two weeks in the greenhouse and the remaining 11 weeks in the induction room, with conditions of light and temperature in each case being approximately the same as those described for treatment five (experiment 3).

At the end of the induction treatment (August 2, 1951) 80 plants were transplanted singly in six-inch pots and divided at random into two groups of 40 each which were placed in the field, in the open, a short distance apart. Comparable control plants, five weeks old, were included in each location. Conditions of light, temperature, etc., were identical for the two groups, except that one (treatment 1) received no supplemental light and the other was lighted continuously. On September 12 all plants were returned to the relatively warm greenhouse where the field lighting system was continued, except that very weak, indirect artificial light reached the plants of treatment 1. While in the field, the two groups were near the plants of experiment 3, and consequently field temperatures listed for that study apply also to experiment 4, omitting the first week.

The results given in Table 3 show that supplemental light was essential for development of normal seed stalks under the conditions of this experiment. It is postulated that the beneficial effect of the artificial light in this case was due to prevention or retarding of the reversal process which is known to be promoted by moderate to high temperatures (3). Reversal may result in failure to bolt or in production of vegetative, essentially sterile,

seed stalks. On November 2, 1951, 26 weeks after date of planting, all seed was harvest from the 38 plants of treatment 2 listed as flowering 10 weeks after induction (Table 3). Average yield per plant was 2.3 grams, and germination of the pooled seed was 77 percent.

Figure 2. Top—Sugar beet seedlings in three-inch pots (four plants per pot) on July 25, 1951, two days before the end of induction period. Induction treatments, from left to right: low, medium, and high temperature, five weeks; low, medium and high temperature, 10 weeks; and control (no induction treatment). Plants of the first six treatments were two weeks old at the beginning of induction; the control plants were approximately four weeks old when the picture was taken.

Bottom—Same treatments as above, seven weeks after the end of induction period; four plants per pot.

Post-Induction Temperature

Since it was known that induction tends to be reversed in moderate to high temperatures (3), and since such temperatures would be encountered frequently in general use of the new seed production method described in this paper, an experiment (number 5) was conducted to study the question of temperature tolerance in the post-induction period. Seedlings 25 days old, of a relatively slow-bolting strain similar to that used in experiment 3,

were given 14 weeks' induction treatment under conditions of light and temperature approximating those of treatment 5 of that study. At the end of induction (November 5, 1951) the plants were transferred singly to four-inch pots and divided into four comparable groups. All four groups were placed on one bench in the greenhouse, one group in the open and the other three in transparent chambers. One chamber was allowed to follow the normal greenhouse temperatures, and the other two were electrically heated. Each chamber was provided with continuous forced ventilation, and each of the four groups was given continuous light. At the end of four weeks all pots were placed on a greenhouse bench, under identical conditions, with supplemental illumination about the same as before.

This experiment is still in progress as this paper is being written and consequently a full report cannot be made at this time. Table 4 gives a summary of seed-stalk counts made eight weeks after the end of induction, together with temperature data. Since each of the 40 plants of treatment 1 (not in chamber) had produced a normal, flowering seed stalk by that time, it was assumed that essentially all of the plants in the experiment had been fully induced.

Table 3.—Effect of Supplemental Light, in the Post-induction Period, on Bolting of Photothermally Induced Sugar-beet Seedlings.

Treatment No.	Supplemental light	Induction	Total plants	Plants producing seed stalks[1]		
				Vegetative type	Normal type	
					Total	Flowering
		Weeks	Number	Number	Number	Number
1	Negligible	11	40	7	5	3
		0	10	0	0	0
2	All-night, 150 W.	11	40	0	39	38
		0	11	0	0	0

[1] Stalks one inch or more in length; counts made 10 weeks after the end of induction.

Comparisons of treatments for temperature effects are valid only for numbers 2, 3, and 4—i.e., the three sets of plants which were inside the chambers. The highlight of these results is the strong tendency toward increased reversal with high temperature. For mean temperatures of 65°, 74°, and 83° F., the total number of plants lacking normal seed stalks was two, seven, and 12, respectively. Expressed as percentages, these figures became five, 18, and 30. This significant trend shows the need for caution with respect to high temperatures during the early part of the post-induction period. It should be noted, however, that the strain used in this study is a slow-bolting type. The reversal problem may be less serious where strains with average bolting tendencies are used. A preliminary experiment has indicated that the reversal tendency expected when the induction period ends during hot weather may be at least partially circumvented by holding the plants in a refrigerated room for several weeks, under artificial light, at an intermediate temperature (e.g., about 60° F.) before transferring them to the field or greenhouse.

Discussion

The results presented in this paper have shown conclusively that the seed production method described is feasible under conditions at Fort

Collins, Colorado. However, exploration of the various phases of the problem worthy of study has only begun. Among the unexplored questions meriting attention is that of light effects—intensity, type, day length, etc.—before, during and after induction. Until more is known about these factors, the use of continuous illumination throughout the entire life cycle is suggested. From various observations—not planned studies—it appears that low light intensity following induction tends to increase reversal action, especially in slow-bolting material.

The need for research on this phase of the problem is particularly urgent because of the relative absence of sunshine during the winter months in some sugar-beet regions.

Another avenue of light study which is especially inviting concerns the production of seed indoors without sunlight. Evidence that such a procedure may be feasible has been obtained at Fort Collins where a small

Table 4.—Effect of Temperature Upon Seed-stalk Development in Photothermally Induced Sugar-beet Seedlings; 40 Plants in Each of 4 Treatments.

Treatment No.	Enclosure[1]	Average temperatures[2]			Plants without seed stalks	Plants producing seed stalks[3]		
		Daily maximum	Daily minimum	Mean[4]		Vegetative type	Normal type	
							Total	Flowering
		°F.	°F.	°F.	Number	Number	Number	Number
1	None	81	57	66	0	0	40	40
2	Trans. chamber	77	58	65	0	2	38	38
3	do	87	67	74	4	3	33	32
4	do	94	76	83	4	8	28	27

[1] The plants of treatment 1 (in the open on a greenhouse bench) served merely as controls for appraisal of the behavior of the treatment-2 population. Plants of treatments 2, 3, and 4 all were in transparent temperature chambers.

[2] Recorded in the shade, by means of thermographs, during the first four weeks following induction. Thereafter, all plants in the experiment were held under identical conditions, with temperatures not greatly different from those shown above for treatment 3.

[3] Stalks one inch or more in length; counts made eight weeks after the end of induction period.

[4] Estimated from thermograph charts—not averages of maximum and minimum temperatures.

NOTE: According to chi-square test, the apparent association between temperatures and numbers of plants with normal seed stalks (treatments 2, 3, and 4) is significant ($P < .02$).

group of seedlings, induced by low temperature and artificial light, subsequently was brought to seed in strong incandescent light without any sunlight whatsoever.

Summary

Through a series of experiments a method has been developed which permits the growing of two successive generations of sugar-beet seed in one year. Induction is accomplished in young seedlings by prolonged exposure to low temperature and continuous artificial light. Moderate to warm growing conditions in field or greenhouse, with continuous light, are maintained before and after the induction period. The complete life cycle—

from seed to mature seed—has been produced in six months, using a relatively slow-bolting strain, and in less than six months with a commercial variety having about average bolting tendencies. Flowering was near 100 percent in each case.

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Trials with Herbicides for Weed Control in Sugar Beets

R. T. Nelson[1]

The development of new chemicals and extended uses of some of the older chemicals has given impetus to the search for selective chemical weeding of sugar beets. The results from one year to the next and from one location to another have been erratic. Yet, among the various chemicals tried, there are those which affect some weeds more harshly than they affect beets. Some of the new herbicides show little or no contact injury but act effectively on growing plants and germinating seeds through the soil medium.

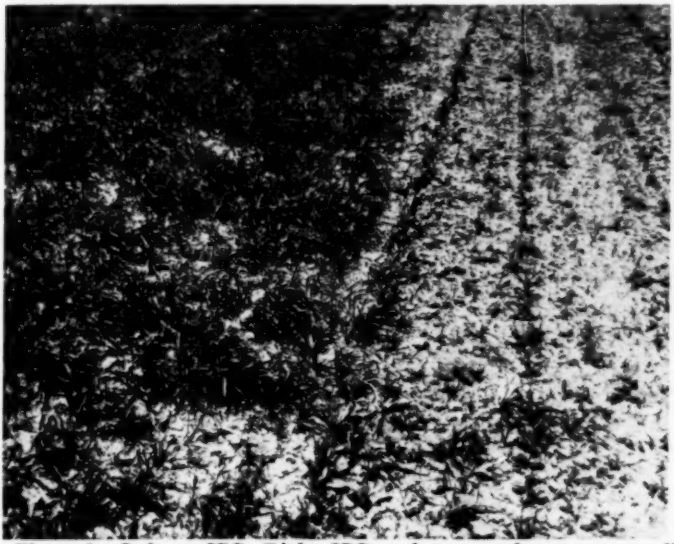

Figure 1.—Left, no IPC. Right, IPC at three pounds per acre, applied as a pre-planting spray and worked into soil with field cultivator and disc. Figures 1, 2 and 3 depict control of foul growth of volunteer barley and wild oats in a sugar beet field near Fort Lupton, Colorado. Application of isopropyl-N-phenyl carbamate was made April 11, 1952, and results photographed May 29.

Since the action of some chemicals is slow, it becomes necessary to observe the chronic effects of herbicidal applications as well as the acute effect. Thus, vigor of crop and weeds after treatment becomes an important criterion in evaluating treatments. Some investigators have used for numerical evaluation of a herbicide the following factors:

$$\text{Tolerance rating of crop} = \frac{\text{stand x vigor (in \% of check)}}{10}$$

$$\text{Herbicidal rating on weeds} = 1{,}000 - \left[\frac{\text{stand x vigor (in \% of check)}}{10}\right]$$

[1] Agronomist, Agricultural Experiment Station, the Great Western Sugar Company, Longmont, Colorado.

The above ratings which may range from zero to 1,000 are helpful in comparing the effects of different treatments. The ideal treatment would be one which gave a tolerance rating of 1,000 and a herbicidal rating of 1,000.

Figure 2.—Closeup view of treated and untreated area. Left, no IPC. Right, IPC at six pounds per acre, applied as a pre-planting spray and worked into soil with field cultivator and disc.

Herbicides tested on small plots in 1951, as pre-emergence and post-emergence spray applications, and rates per acre follow. All sprayable materials were applied in water at a rate of 40 gallons per acre. The herbicides used and range of applications in rates per acre were:

E.H. 5722 at 4-16 pounds; IPC and Chloro-IPC at 4-16 pounds; M.E. 3003 and Niagrathal (Endothal formulations) at 2-8 pounds; TCA, Na salt and TCA, Ca salt at 5-15 pounds; Dichloral urea at 1.5-30 pounds; CMU at 1/4-3 pounds; Xanthogen disulfide at 7.5-30 pounds; Chlorosol-A at 50 pounds; 6Q8 (phthalamic derivative) at 2-8 pounds; E. C. 3890 at 4-8 pounds; and Na isopropylzanthate at 15 pounds.

A summarization of the results of the above trials showed (1) aid in controlling weeds, without serious injury to beets, was obtained in certain cases with the salts of TCA, dichloral urea, IPC, Chloro-IPC, and Endothal;

(2) pre-emergence applications gave better weed control than post-emergence applications; (3) the weeds controlled were for the most part small seeded annual grasses.

Pre-emergence and post-emergence herbicidal applications have not given consistent results in northern Colorado. Consequently trials were started in which the herbicide was applied and worked into the soil as a pre-planting treatment. The limited trials completed to date using this method have given good results with a high degree of consistency. Further,

Figure 3.—General view of treated and untreated area. Left, no IPC. Right, IPC at six pounds per acre, applied as a pre-planting spray and worked into soil with field cultivator and disc.

such large seeded grasses as wild oats and volunteer oats and barley have succumbed to this treatment.

Three trials were made during the spring and summer of 1951 using IPC (emulsifiable) and dichloral urea (E. H. 2). In the first trial, IPC was used at 20 pounds per acre and E. H. 2 (73 percent dichloral urea) at 40 pounds per acre. Barley and sugar beets were planted immediately after the chemicals had been applied and hoed into the soil to a depth of four inches, April 4. No barley emerged on the treated plots. The beets did not emerge on the IPC plot and emergence was somewhat retarded on the E. H. 2 plot. Barley and sugar beets were replanted on both plots April 26. Following this planting the beets emerged normally on the plots which had been treated April 4, with IPC and E. H. 2. Again the barley failed to emerge on either treated plot.

Trial two employing preplanting application included IPC at 4, 8, and 16 pounds per acre and E. H. 2 (73 percent dichloral urea) at 2, 4, 8, 24, and 40 pounds per acre. After application the herbicides were worked into

the soil to a depth of three-four inches by hoeing. Previous to the applications of herbicides a 1-1-1 mix of Trebi barly, Clinton oats, and wild oats was broadcast and worked into the soil. Immediately after the application of the herbicide commercial segmented sugar beet seed was planted with a Milton planter, April 28. Sugar beets emerged acceptably on all plots. Grain and wild oat control on the IPC-treated plots was excellent. Some grain emerged on all E. H. 2 treated plots but marked suppression in rate of growth of the grain started at the eight pound rate.

Trial three, employing preplanting application of herbicide, was a demonstration made on 22 x 50-foot plots. For this trial Chloro-IPC, TCA and Endothal were added to IPC and E. H. 2 herbicides used in Trials 1 and 2. In this case the land was (1) partially prepared for beets so that there was no gross unevenness of the surface; (2) the barren soil surface was sprayed with herbicides at rates as listed below in 40 gallons of water per acre; (3) immediately after spraying the soil was disced to incorporate the herbicides with the surface four inches of soil; (4) to simulate foul grain growth a 1-1-1 mixture of oats, barley, and wild oats was drilled deep and shallow with a grain drill; (5) seedbed was completed and commercial segmented seed planted with a Milton drill, and (6) irrigation was made with overhead sprinkler system. The operations were performed July 16 and 17.

Treatments used in trial three in rates per acre were: IPC at three and six pounds; dichloral urea at 7.5 and 15 pounds; Chloro-IPC at three and six pounds; TCA at 15 pounds, and Endothal at 7.6 pounds.

Again volunteer grain and wild oat growth was stopped or markedly suppressed on the treated as compared to the untreated areas. Emulsifiable IPC at three and six pounds per acre gave fair and excellent control, and dichloral urea at 7.5 and 15 pounds per acre gave poor and good control, respectively. Control with TCA at 15 pounds per acre was good and comparable in effectiveness with dichloral urea at equal rate. Endothal gave very good control of the wild oats and grain but at the rate used (7.6 pounds per acre) some retardation was noted in the rate of growth of beets. As in observations on post-emergence sprays with Endothal, the injury was temporary. In other tests, beets have survived contact injury from rates of six pounds Endothal per acre applied as a post-emergence spray to beets and weeds. The Chloro-IPC gave much the same result as standard IPC at the six-pound rate, but appeared inferior at the three-pound rate.

In general soil incorporation of the herbicides found to be tolerated by beets gives better weed control than later application. A possible exception to this is Endothal which has also performed well in post-emergence spray trials made on grasses and certain broadleaf weeds.

Summary

Of fourteen herbicides tested IPC, Chloro-IPC, E. H. 2 (dichloral urea), Endothal and TCA gave some weed control without serious injury to beets. Grass control was improved when herbicides were applied and disced into the soil prior to planting sugar beets. Oats, barley and wild oats were all controlled when above herbicides were incorporated with the soil at the

approximate time of seed germination. IPC (emulsifiable) at three and six pounds per acre gave fair and excellent control, respectively, and appeared slightly more effective than Chloro-IPC. Dichloral urea and TCA gave marked suppression of volunteer small grain growth, and wild oats at 15 pounds per acre. Endothal at 7.6 pounds per acre gave very good control with slight injury to beets. Endothal shows promise also, as a post-emergence spray, on grasses and some broadleaves. Beets survived contact injury of six pounds Endothal per acre.

Results with T.C.A. on Barnyard Grass Control in Sugar Beets in Montana and Wyoming

C. E. Cormany and E. G. Eckroth[1]

One of the most vital things in the development of a beet crop is the control of weeds when the beet plants are in the seedling stage. Great progress has been made in this direction with the use of chemical sprays, both before the beet seedlings emerge and after emergence. When the right chemical is found and the proper method of applying it, a great stride will have been made.

In 1949 several chemicals were used on an observational basis at the Holly Experiment Station at Sheridan, Wyoming. Most of these had little or no value. However, two which had shown promise in 1949 were incorporated into a replicated test in 1950 and are reported herewith.

Table 1.—Results with Pre-emergence Weed Sprays on Sugar Beets at Sheridan, Wyoming, in 1950.

Treatment No.[1]	Beet seedlings per 100 ft. of row	Plants per Sq. Ft. of row			Stand after thinning	Acre Yield		
		Grass[2]	Broadleaf	Total		Gross Sugar	Tons	% Sucrose
1	362	17	1	18	107	3,554	10.544	16.90
2	366	24	2	26	83	3,286	9.720	16.94
3	458	53	5	58	87	2,293	6.779	16.93
S. E. of Mean						71	.238	.12
Sig. Diff. (5%)						231	.776	ns
S. E. M/Gen. Mean (%)						2.33	2.64	.74

[1] 1. Sodium TCA—12½ lbs. per acre in 22 gal. water applied four days after planting.
2. Di-nitro-secondary butyl phenol—one and one-half pts. with one and one-half gal. diesel oil and 21 gal. water applied four days after planting.
3. Check—no treatment.

[2] Average of 10 counts. Taken from an area in row six inches wide and 24 inches long, 18 days after planting.

[3] Barnyard grass (*Echinocloa crus-galli*)

The spring of 1950 was late but rainfall was about normal. Seed beds were spring plowed and poor stands were the rule. Early weed growth was extremely fast. Under these conditions excellent weed control was obtained by an application, four days after planting, of 12½ pounds per acre of Sodium T.C.A. in 22 gallons of water per acre, and also a mixture of di-nitro secondary butyl phenol at the rate of one and one-half pints with one and one-half gallons of diesel oil in 20 gallons of water. Data in Table 1 indicate that at least two-thirds of the grasses were controlled by T.C.A. and the stand after thinning increased about one-fourth. Yields of the treated plots also significantly outyielded the check.

Rainfall was ample after applications were made. A rain of .11 inches on the day after applying the sprays was followed by two other rains during the week. This moisture, no doubt, dispersed the spray material into the soil very effectively in the areas occupied by the grass seed which germinated.

[1] Chief Agronomist and Associate Agronomist respectively, Experiment Station, Holly Sugar Corporation, Sheridan, Wyoming, and Sidney, Montana.

No record was kept on relative cost of weeding the treated and untreated plots but the time consumed for the check plots was estimated to be at least four times as much as for the T.C.A.

Seedlings on the di-nitro secondary butyl phenol plots showed no effect of the spray. Seedlings in the T.C.A. plots showed a slightly yellowed appearance the first week but quickly regained the normal green color.

T.C.A. had outstanding value at the rate of 12½ pounds per acre. A lower rate would probably be effective. Di-nitro secondary butyl phenol also was promising.

In 1951 a followup of the 1950 pre-emergence test with T.C.A. was conducted on a very grassy field. Three rates (five, seven and one-half and 10 lbs.) at three dates (1) immediately after planting, (2) a week after planting, and (3) two weeks after planting were used. Also, a comparison between Sodium T.C.A. and Calcium T.C.A. at the seven and one-half-pound rate was included, as well as the use of 40 percent Technical Endothal at the then recommended rates of five, 10 and 20 pounds per acre.

An extremely dry period of about three weeks following the planting of the test afforded a much different condition of soil than in 1950. Germination of beets and weeds was slow and it was necessary to irrigate the field before beets would sprout. Resulting stands were irregular and the test was abandoned after making a few weed counts. Data secured indicated that the use of T.C.A. at rates of seven and one-half pounds and above retarded growth of all grassy weeds and that there was little, if any, difference between Calcium T.C.A. and Sodium T.C.A. Endothal at these rates was quite effective in controlling broadleaf weeds also.

In an observation area, Endothal at the 10-pound per acre rate had little effect on the beet seedlings but completely eliminated the button weed (Malva) and retarded the growth of wild oats. It was very promising for Malva control and will be followed up in 1952.

At several of the factory areas in which Holly Sugar Corporation operates, strip tests with T.C.A. were conducted in commercial fields in 1951. Extremely dry weather following planting seemed to limit effectiveness of the T.C.A. Under dry conditions where irrigation was necessary to germinate the beets, T.C.A. was more effective on the lighter textured soils. In some cases, such as those at Sidney and Hardin, Montana, a thorough irrigation even three weeks after planting resulted in fair control of grassy weeds and much grower interest in its further use.

Summary

Results of test in the Sheridan, Wyoming, area indicate good control of grassy weeds with Sodium T.C.A. when rainfall following planting is adequate. Heavy irrigations in dry seasons to sprout beet seeds have merit but did not seem to equal rainfall in effectiveness. On commercial fields T.C.A. was most effective on lighter soils following irrigations.

Results of Experiments on Chemical Weed Control in Sugar Beets

A. R. Downie, D. B. Ogden, and J. C. Tanner[1]

The use of chemicals for the control of weeds in sugar beet agriculture is relatively recent. The chief impetus for this phase of research was furnished by the results obtained by Robbins and Bainer in 1947 (1)[2]. Several of the sugar companies tried pre-emergence weed control tests following the leads which had been established by these two workers. Also about this time other agencies became interested in experimentation with herbicides to control weeds in sugar beets. In the last four years cooperative and independent testing of chemicals has been carried on by the Beet Sugar Development Foundation, the United States Department of Agriculture, state experiment stations, commercial chemical companies, and by individual sugar companies.

Table 1.—Average Number Beets (B) and Grasses (G) in T.C.A. Treated and Non-treated Areas in 3 Different Fields—1950.

Field No.	No Treatment		5 lbs. T.C.A.		10 lbs. T.C.A.		15 lbs. T.C.A.		20 lbs. T.C.A.		25 lbs. T.C.A.	
	B	G	B	G	B	G	B	G	B	G	B	G
1	55	24	67	2	54	1	57	1	....	....	....	....
2	32	42	29	10[1]	24	8[1]	23	2	29	0	....	....
3	46	17	50	3[1]	51	1	40	1	40	0	....	....

[1] These grasses died within one week after counts were made.

A large number of chemicals have been screened as to their herbicidal effects and this information has been fairly well disseminated to the workers in this particular field. As yet no one chemical appears to be effective in controlling all of the weeds in the different beet growing areas and it appears that the answer may be the use of specific chemicals for specific kinds of weeds.

The results of small plot tests in 1949 indicated that sodium trichloroacetate might hold some promise as a control for annual grasses. Since annual grasses are the principal weeds in the beet growing areas of southern Minnesota, northern Iowa and south-central Nebraska, it was decided to explore the possibilities of this herbicide for the specific problem which exists in these areas. The purpose of this paper is to present the results obtained in the strictly experimental phases of this problem. The results obtained in the commercial application are presented by Robinson and Quamme (2).

Methods and Materials

Sodium trichloroacetate was applied either as a pre-emergence or post-emergence spray in all experiments reported. In all cases the 90 percent material was used, and unless otherwise noted was applied in 30 gallons of water per acre as a blanket application.

[1] Plant Pathologist, Rocky Ford, Colorado, and Research Assistants at Mason City, Iowa, and East Grand Forks, Minnesota, respectively, American Crystal Sugar Company.

[2] Numbers in parentheses refer to literature cited.

The grassy weeds which were encountered most frequently in all of the test areas were:

Green foxtail	*Setaria viridis*
Yellow foxtail	*S. lutescens*
Burr bristlegrass	*S. verticillata*
Barnyard grass	*Echinochloa crusgalli*
Annual bluegrass	*Poa annua*

Table 2.—Average of Yields and Sucrose Content of Treated and Non-treated Plots (From five fields) in Mason City District—1950.

Rate T.C.A. Lbs. per A.	Tons Beets per Acre	Percent Sucrose	Lbs. Sugar per Acre
5	11.34	14.8	3,445
10	12.48	14.9	3,755
15	11.40	14.6	3,368
20	11.57	15.7	3,641
25	8.98	16.6	2,981
Untreated	10.76	14.8	3,067

Results

Tests in 1950 consisted of six-row plots in five farmers' fields in the Mason City territory. In most instances these strips were only 200 feet long. The rates of application were 5, 10, 15, 20, and 25 pounds of 90 percent T.C.A. per acre as pre-emergence spray treatments. As indicated by the results in Table 1 all of the rates of treatment effectively controlled the grass weeds. The data for this was secured by counting the number of grass seedlings in an area 12 inches x 6 inches running parallel to the beet row. Five such counts were made in each field for each treatment. Also five beet counts were made per 100 inches of row for each treatment. Each figure is the average of five counts.

The light rate of five pounds proved to be about as effective as the heavier rates. Not only was the grass almost entirely eliminated by thinning time but there was no further growth of grass in the treated areas for the rest of the growing season. However, the year following treatment, the growth of grass in some of these areas was just as luxuriant as it was in the areas untreated the previous year.

The yields in tons and pounds sugar per acre and sucrose content of the beets are presented in Table 2.

The results from these tests in 1950 were so uniform that it was tentatively determined to do some commercial application in 1951 and also expand the experimental work to determine the minimum effective rate of application as well as to determine whether the gallonage of the carrier could be cut enough so that low volume sprayers could be employed.

Pre-emergence and post-emergence tests were made in the Mason City, Grand Island, and Rocky Ford areas in 1951.

Four field tests were made in the Mason City districts to determine whether reduced gallonage sprays would be as effective as the 30- and 40-gallon rates which had been used in previous tests. There were two rates

of treatment for the T.C.A., namely: five pounds and eight pounds of 90 percent material per acre. Each rate was applied as a blanket application in 10-, 20-, and 30-gallon per acre treatments. Yields were not procured for these experiments; however, grass weed control was equally satisfactory with all of the treatments.

In another test made in the Mason City area, an experiment was made to determine the effects of rate and time of treatment on yields of beets and on the effectiveness of grass control. The rates and stages of treatments and results for this experiment are given in Table 3. This experiment was made as a randomized block with three replications. The plots were eight rows wide and 50 feet long. All rates of T.C.A. were applied in 30 gallons of water per acre.

Table 3.—Results Obtained with Two Rates of Treatment of 90 Percent T.C.A. at the Designated Stages of Beet Growth. Mason City, Iowa—1950.

Rate T.C.A. Lbs. per A.	Beet Stage at Treatment	Tons Beets per Acre	Percent Sucrose	Lbs. Sugar per Acre
5	Time of Planting	19.11	16.8	6,438
10	Time of Planting	19.70	17.2	6,773
5	Barely emerging	19.80	17.0	6,713
10	Barely emerging	17.64	17.3	6,078
5	Cotyledon to 2 leaf	18.67	16.5	6,142
10	Cotyledon to 2 leaf	16.77	17.5	5,866
5	4 to 6 leaf stage	17.57	17.2	6,051
Checks		17.22	17.4	5,978
Difference required for Significance		2.01	.70	555

The data presented in Table 3 quite clearly indicate that maximum benefits are obtained in pre-emergence treatments. There is a marked drop in tonnage yield with the 10-pound treatment rate when applied as a post-emergence treatment. This also holds true for the five-pound rate but to a lesser degree. This drop in tonnage is undoubtedly caused by the marked dwarfing effect on the beets which is evident from two to four weeks after the application of post-emergence treatments with T.C.A. However, regardless of this definite injury to the beets in post-emergence treatments none of the treatments was significantly lower than the untreated plots. However, in beets planted late in the season post-emergence treatment for grass control could very possibly make a marked difference in yield.

Table 4.—Effect of Different Rates of Treatment of T.C.A. on Tonnage, Percent Sucrose, and Pounds Sugar per Acre of Sugar Beets. Mason City, Iowa—1951.

Rate T.C.A. Lbs. per A.	Tons Beets per Acre	Percent Sucrose	Lbs. Sugar per Acre
2	18.02	17.7	6,361
3	18.06	17.6	6,338
4	17.77	17.3	6,148
5	18.79	17.4	6,552
6	18.05	17.3	6,249
7	18.94	17.2	6,526
Difference required for Significance	2.28	.45	758

Rates of treatment with T.C.A. were also tried in this area. T.C.A. at the rates of two, three, four, five, six and seven pounds was applied in 30 gallons of water per acre as pre-emergence treatments. Each plot was eight

rows wide and 50 feet long and each treatment was replicated three times. Grass control was satisfactory in all treatments until after thinning time. No grass was hoed out of the plots after the beets had been thinned. Only the broadleaf weeds were pulled. Just prior to harvest, grass was appearing above the beet foliage in the two, three, and four pound rates. The five, six and seven-pound rates of application held the grass in check for the entire season.

Table 4 presents the yields obtained in the above test.

Although the data indicate no significant differences in yield, there would definitely have been a saving in labor over any untreated check. Also if these plots had been harvested with a harvester grass roots in the two-, and three-pound rates would probably have given a little trouble.

Two pre-emergence tests with T.C.A. were made in the Grand Island area. Only one of these tests was harvested. The test consisted of five treatments replicated three times. The plot size was six rows wide and 50 feet long. The results of this test are given in Table 5.

Table 5.—The Effect of Pre-emergence Treatment with T.C.A. at the Designated Rates on the Yield of Sugar Beets. Grand Island, Nebraska—1951.

Rate T.C.A. Lbs. per A.	Tons Beets per Acre	Percent Sucrose	Lbs. Sugar per Acre
4	17.69	13.37	4,644
8	16.78	13.32	4,453
12	16.35	14.03	4,592
16	15.88	13.87	4,420
Check	14.82	14.07	4,128
Difference required for significance	3.46	.93	927

Two post-emergence tests were also run in this area but again only one of the tests was harvested. The spray treatments were applied when the beets were in the cotyledon to the very early two-leaf stage and in all cases there was a stunting of the beets. This stunting was especially severe at the eight- and 10-pound rates. The data for this experiment are presented in Table 6.

Table 6.—Effect of Post-emergence Treatment with T.C.A. at the Designated Rates on Yields and Percent Sucrose of Sugar Beets. Grand Island, Nebraska—1951.

Rate T.C.A. Lbs. per A.	Tons Beets per Acre	Percent Sucrose	Lbs. Sugar per Acre
2	14.20	13.25	3,764
4	16.32	12.18	3,934
6	16.32	13.62	4,411
8	15.37	13.00	4,007
10	16.73	13.53	4,507
Check	15.91	12.78	4,045
Difference required for significance	2.70	1.24	759

The results on the tests reported in both Tables 5 and 6 were obtained from adjacent rows in the same field, the only difference being in time of treatment. Grass control was excellent except in the two-pound post-emergence treatment. Besides grasses there were also pigweeds present in this field. The pigwed was definitely stunted at the 12-pound pre-emergence rate and better than an 80 percent kill was obtained at the 16-pound pre-emergence rate.

Although neither test shows significant differences in yield, the general tendency is for the pre-emergence treatments to outyield the post-emergence treatments.

An interesting sidelight developed in the tests in this area. Precipitation totaled 7.11 inches within four weeks after the pre-emergence treatments. It was assumed that an excess of rainfall might leach the T.C.A. too deep and either make it inoperative for grass control or cause injury to the beets. In spite of the heavy rainfall the treatments controlled the grass weeds and there was no apparent injury to the beets.

Both a pre-emergence and post-emergence test were conducted at Rocky Ford, Colorado. Only the post-emergence test was harvested. The results for this test are presented in Table 7.

Table 7.—Effect of Post-emergence Treatment with T.C.A. at the Designated Rates on Yields and Sucrose Percent of Sugar Beets. Rocky Ford, Colorado—1951.

Rate T.C.A. Lbs. per A.	Tons Beets per Acre	Percent Sucrose	Lbs. Sugar per Acre
4	18.32	15.69	5,733
6	14.82	13.80	4,090
8	16.01	14.85	4,853
10	17.12	14.79	5,107
Check	14.36	15.16	4,364

Although there were only two replications in this experiment it is probable that the differences in yield are fairly reliable. Certainly the grass was controlled effectively.

There was no precipitation for three weeks after the spray had been applied. During this period, there was little visible evidence of grass control in spite of the fact that the field had been irrigated after treatment. A total of one and ninety-one one-hundredths inches of rainfall was obtained during the fourth week. Five weeks after treatment all of the grass was dead in the treated plots.

Also, in the pre-emergence test, in spite of the fact that the beets had to be irrigated up there was little evidence of grass control until after the rains. From this experience and similar experiences in previous years it is evident that T.C.A. when sprayed on the surface is only effective in grass control when it has been leached down into the root zone of the grasses. This can not be accomplished by row irrigation.

Additional experimentation is necessary to determine whether incorporating the T.C.A. in the upper three or four inches of soil will make it effective as a grass control under conditions of row irrigation with no intervening spring rains.

Discussion

T.C.A. definitely has a place in the control of annual grasses other than wild oats in sugar beet agriculture. From the three years experience of using T.C.A. at the rates effective for grass control there seems to be no residual effect on crops which follow sugar beets. In areas where beet

agriculture is dependent on rainfall the problem of buildup of T.C.A. in the soil will probably be of minor importance.

T.C.A. may not be immediately effective in a very dry spring; however, there is some evidence that in the eastern areas only one-half inch of moisture is necessary to carry the chemical to the root zones of seedling grasses.

Summary

1. Sodium trichloroacetate (90%) used as a pre-emergence spray treatment in sugar beets adequately controlled annual grasses in northern Iowa, southcentral Nebraska, and at Rocky Ford, Colorado.

2. Between five and seven pounds of 90 percent T.C.A. applied in 10 to 30 gallons of spray material per acre seem to be an adequate dosage for control of most annual grasses.

3. Adequate rainfall seems to be necessary in order for the T.C.A. to be effective.

4. Pre-emergence treatments are more effective than post-emergence treatments.

5. T.C.A. at the dosages tried had little if any effect on sucrose content of the beets and did have a tendency to increase yields.

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Results Obtained by Sugar Beet Growers Through the Use of TCA[1] for the Control of Pigeon Grass[2] in Southern Minnesota and Northern Iowa During 1951

P. T. Robinson and A. G. Quamme[3]

In southern Minnesota and northern Iowa, the weed that presents the greatest problem to sugar beet culture is pigeon grass. Primarily as a result of the cropping system of the area, pigeon grass grows in the fields in such profusion as to literally create a sod condition in the beet row. Thinning of sugar beets is made difficult, and the timeliness of the operation is often lost. Beet seedlings experience tough competition for the available moisture and fertility, thus adversely affecting maximum growth.

Following the Northwestern Weed Conference at Fargo, North Dakota, in the spring of 1949, Quamme and Ogden (1)[4] undertook extensive experimental chemical weed control plot work wherein some thirty treatments of various chemicals in varying rates and concentrations were compared. The outstanding control of grasses in the TCA plots, accompanied by no apparent damage to the beets, was so pronounced that strip work on growers' fields was undertaken in 1950. Again, the results were very outstanding and an energetic program was undertaken to acquaint the beet growers with the benefits of this practice.

In 1951 a number of growers sprayed 5,473 acres of sugar beets in southern Minnesota and northern Iowa. In practically all instances the material was applied as a pre-emergence spray at a rate of six to eight pounds 90 percent Sodium TCA in 20 to 30 gallons of water per acre. A few growers used the liquid 50 percent Sodium TCA at a rate of five pounds per gallon per acre.

The results obtained were extremely gratifying to growers and field workers alike. In all but a few instances, where failure could be traced to improper dosage or improper premixing, the pigeon grass was controlled satisfactorily. Growers required a lesser number of workers to thin a given acreage of beets, and, by the same token, the workers' daily earnings were increased. Despite continuing rains which kept all field workers idle for a period of ten days at a time when the thinning load was at its peak, the grass was effectively controlled by the chemical so that no weed problem developed. The control was effective over a period of six to eight weeks. It is probable that varying conditions in future years may present new problems, but several conclusions have been reached through the program of the past years, permitting thereby certain definite recommendations which are:

Ground spraying is preferable to application from airplane. Proper

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[1] Sodium Trichloroacetate.

[2] The term "Pigeon Grass" as used in this article is the common name for green foxtail (*Setaria Viridis*) and yellow foxtail (*Setaria Lutescens*).

[3] Managers Chaska, Minn., and Mason City, Iowa, respectively, American Crystal Sugar Company.

[4] Numbers in parentheses refer to literature cited.

coverage is all-important and planes are rarely able to economically apply the 20 to 30 gallons per acre recommended rate. Since the important avenue of entry for the chemical is through the roots, it will be realized that the 20 to 30 gallons of water recommended per acre is simply to insure proper mixing and complete coverage. Precipitation in sufficient amounts must follow to insure the chemical being carried down to the roots. One inch of precipitation is sufficient to accomplish this. As of interest, however, the six and one-half inches of rain which was received in 1951 over a four-week period did not detrimentally affect the response to the treatment.

If the sprayer has been previously used for 2,4-D work, a thorough cleansing is necessary. One quart of household ammonia in the sprayer filled with water will neutralize the acid. Soda can be used satisfactorily, or one of the several commercial products sold for this purpose, such as Nutra-Sol available at a cost of approximately 75c a treatment. A thorough pre-mix of the TCA in water is imperative. The powder is soluble in water and approximately four pounds can be dissolved in a gallon of water. Warm water simplifies this process very materially. Nozzle plugging can be avoided by straining the material when emptying into the sprayer. The use of liquid TCA eliminated the problem of securing a complete mix such as encountered in the case of powder; however, until this year chemical companies did not offer a container suitable for carrying over any excess material from one year to the next. Corrosion of equipment is not a problem since the material used had an inhibitor added. It is necessary only to thoroughly wash out the tank and boom with water following each usage.

Proper rate of application of TCA and gallonage of water must be accurately controlled. The proper nozzles, proper pressure and proper ground speed will result in the desired application. Use of a spray meter and a tractor speedometer are recommended. The boom should be so adjusted that the spray from the nozzles does not overlap more than an inch or two.

In comparison field tests, it has been determined that such susceptible crops as soy beans, corn and most of the clovers apparently can be planted with safety the second year after spraying of the preceding crop had been made.

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Correlation Between Soil Type and Rates of Sodium TCA and 3-Chloro IPC Application for Pre-emergence Grass Control

ROGER BLOUCH AND J. L. FULTS[1]

When field results with 3-Chloro IPC and Sodium TCA were being tabulated at the close of the 1951 growing season, certain inconsistencies appeared.

Identical rates of application under identical temperature and moisture conditions produced totally different results in several localities. In the Greeley area, for instance, 3-Chloro IPC at one and one-half pounds per acre gave 30-50 percent control of grass weeds, while the same rate at Fort Collins gave no results whatever. TCA injured onions severely at 10 pounds per acre at Greeley, but removed grasses effectively from onions at Fort Collins without apparent injury to the crop.

An analysis of the conditions present in the various testing areas revealed one variable, the soil type. In order to test the validity of this finding, three widely divergent agricultural soil types common to northern Colorado were selected and placed in deep flats. These soils, Valentine fine loamy sand, Fort Collins loam, and Terry silty clay loam were planted to field depths with sugar beets, onions, sweet clover and alfalfa, wild oats, millet, barley, and crested wheatgrass. Three-Chloro IPC at 3, 6, 9, and 12 pounds per acre, and Sodium TCA at 5, 10, and 15 pounds were compared against untreated checks in each soil type.

Results show conclusively that the selective effect against grasses of either chemical per unit weight is far less on the sand and clay than on the productive, highly organic loam. The lowest rates of TCA and C-IPC injured all crops on the sandy soil, and all but the lowest rate injured crops on the clay, whereas sugar beets were uninjured in the loam at 15 pounds per acre of TCA. Barley did not appear in any of the flats containing the sandy soil, but germinated and grew normally at six and nine pounds per acre of C-IPC on loam. The other crops and grasses responded similarly.

This comparison under controlled conditions closely paralleled the field results obtained earlier, and indicates a high degree of necessity in properly gauging field rates of application with the varying soil types encountered.

To date it appears that organic matter and structure are probably more of a factor than is texture. This is brought out by the similar lack of resistance to the action of the chemicals by both sand and clay. The medium-textured loam, with high organic content and friable structure, probably adsorbs the chemicals to a high degree and prevents effective usage of a large percent of the total amount applied. Differences in residual effects on these various soil types will also be studied, in an attempt to arrive at a usable index for determining rates of application of pre-emergence grass herbicides.

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Chemical Control of Annual Grasses in Alfalfa, Sugar Beets, Onions, and Certain Truck Crops

ROGER BLOUCH, J. L. FULTS AND B. J. THORNTON[1]

Three-Chloro IPC, sodium TCA, and maleic hydrazide (MH30) were field-tested in three areas of Colorado for selective action against annual grasses.

Results with pre-emergence sprays of 3-Chloro IPC on onion seed beds near Greeley showed that one and one-half pounds per acre gave 30-50 percent control of stinkgrass (*Eragrostis cilianensis*), barnyard grass (*Echinochloa crus-galli*), and witchgrass (*Panicum capillare*). The onions showed no injury.

Sodium TCA at 10 pounds per acre gave only 20 percent control of the grasses, and produced severe chlorosis in the onions. The soil was sandy in texture, and moisture abundant. On a heavy clay soil near Fort Collins, 3-Chloro IPC at one and one-half pounds was ineffective, whereas sodium TCA at 10 pounds gave 90-100 percent control. In this treatment, sodium TCA did not injure sugar beets, but did severely injure lettuce, red beets, and cucumbers.

In a later trial on loamy soil, 3-Chloro IPC at six pounds gave 100 percent control of green foxtail (*Setaria viridis*) and 40 percent control of wild oats (*Avena fatua*). Onions, alfalfa, and sweet clover showed no injury, but sugar beets were stunted for a period of four to six weeks. Again moisture conditions were adequate.

In the subnormally dry San Luis Valley, near Center, spring treatments with 3-Chloro IPC, sodium TCA, and maleic hydrazide (the latter post-emergence) were ineffective in the control of wild barley (*Hordeum jubatum*) and volunteer grain in second-year alfalfa pastures. Evidently conditions must be favorable for plant growth before these herbicides can function effectively.

Fall treatments in the same area with 3-Chloro IPC at six pounds, follower by flood irrigation, gave 95 percent control of volunteer oats in five-month-old alfalfa. The alfalfa showed no injury at this rate. Sodium TCA at 10 and 20 pounds gave no control of the volunteer oats. Soil texture varied on the plots from sandy to gravelly. From the results obtained in all three areas it would appear that 3-Chloro IPC is better adapted to lighter-textured soils, and sodium TCA to heavier soils, with both chemicals requiring adequate moisture for efficient results. Maleic hydrazide in greenhouse trials effectively prevented awn formation without leaf-kill in wild barley at one and one-half and three pounds per acre.

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[1] Research Assistant, Professor and Associate Professor and Head of Seed Laboratory, respectively, Colorado A & M College.

Reclamation of a Saline-Alkali Soil by Leaching and Gypsum Treatments Using Sugar Beets as an Indicator Crop[1]

LOUIS C. BOAWN, FRED TURNER, JR., C. D. MOODIE, AND C. A. BOWER[2]

Introduction

Several rather extensive areas of alkali[3] soils occur in the Yakima Valley of Washington. From the standpoint of topography, texture, and profile depth, these soils are highly suitable for irrigation agriculture and, were it not for their alkali nature, would probably be among the most productive soils of the area. Attempts are being made to farm many of these soils, but at best, production is uncertain and reduced because of the alkali "spots" where crops fail to grow.

The purpose of the experiment reported in this paper, which is part of a more comprehensive research program, was to determine the effect of leaching and gypsum treatments upon the removal of exchangeable sodium and soluble salts and finally the effect of these treatments upon crop growth. Ultimately, the goal of the research program is to determine the most direct and economical means of bringing the alkali soils of this area into useful production.

Sugar beets were used as an indicator crop. Because of their high cash value, salt tolerance, and possible benefit from the sodium ion as a nutrient, they should be a desirable crop for farmers of the area to produce.

Procedure

The experimental plots were located about three miles south of Toppenish, Washington, on Umapine fine sandy loam. Sixteen 20- by 30-foot plots were established on alkali spots which were reasonably uniform and in all cases devoid of vegetation. The surface six inches of soil in the plots had a pH of 9.5 to 10.0, an exchangeable sodium-percentage of 60 to 70, and an electrical conductivity of the saturation extract greater than 10 millimhos per centimeter. All of these saline and alkali properties decreased gradually with depth and approached values characteristic of a normal soil in the 24-36 inch layer.

During 1949, eight of the 16 plots were diked and flooded with water in six-inch increments until a total of 30 inches of water had been applied. The effect of this flooding upon exchangeable sodium and salt removal was followed by analyses of soil samples taken before, during and after the flooding operations.

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[1] Scientific Paper No. 1086, Washington Agricultural Experiment Stations, Pullman. Project No. 882. This paper is based on a thesis submitted by the senior author to The State College of Washington in partial fulfillment of the requirements for the degree of Master of Science in Agriculture (1).[4] The research was performed under a cooperative agreement between the Utah-Idaho Sugar Company, the Washington Agricultural Experiment Stations, and the Bureau of Plant Industry, Soils, and Agricultural Engineering, U.S.D.A. The authors wish to acknowledge their indebtedness to the Utah-Idaho Sugar Company for the research grant and assistance with field operations. Appreciation is also extended to the many individuals of the cooperating agencies for their advice and guidance.

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[3] The term *alkali* is used in this paper to designate a soil having an exchangeable-sodium-percentage exceeding 15.

[4] Numbers in parentheses refer to literature cited.

In the spring of 1950, the plot dikes were broken down and the entire field planted to sugar beets. The customary cultural practices for the area were followed except that pre-emergence irrigation (2) was applied. Previous to planting, one-half of the flooded plots and one-half of the unflooded plots were treated with agricultural gypsum at a rate of 10.4 tons per acre. Thus four treatments were established: (a) no treatment, (b) leaching-without-gypsum, (c) leaching-plus-gypsum, and (d) gypsum alone. Soil changes resulting from these treatments during the growing season were followed through analyses of soil samples taken before planting and at harvest time. The effect of the treatments upon sugar beet growth was determined by stand counts before thinning, after thinning, and at harvest time, and by tonnage yield.

Results and Discussion

Effects of Leaching, Gypsum, and Furrow Irrigation upon Soluble Salts, Soil Reaction, and Exchangeable Sodium

Effect of Leaching.—Soluble salts were rapidly removed from the surface three feet of soil as a result of leaching (Figure 1). After flooding with 12 inches of water, the surface foot of soil had been reduced to a non-saline condition, but a considerable portion of these salts had accumulated in the 12-36 inch layer. Following another 12 inches of flooding, however, the salts had been moved beyond the 36-inch depth, leaving the upper three feet of soil free of excess salinity. The final six-inch application of water produced no significant change in salt content at any depth; the electrical conductivity of the saturation abstracts tends to approach a rather high

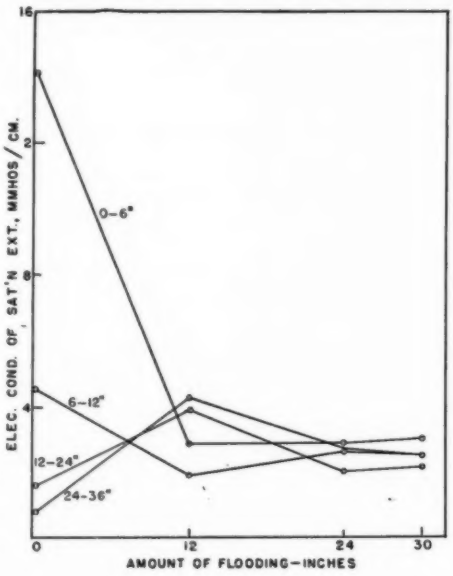

Figure 1.—Soluble salt content (conductivity of saturation extracts) of four soil layers as affected by leaching (averages of four plots).

minimum of around two and five-tenths millimhos per centimeter. Essentially no change in pH occurred at any depth as a result of leaching.

The effect of leaching upon the replacement and movement of exchangeable sodium is shown in Figure 2. Exchangeable sodium was not readily removed by leaching, and even after 30 inches of flooding only about 17 percent of the exchangeable sodium in the surface six inches had been displaced. Sodium moved gradually through the profile and the action of a given six-inch addition of water was to move sodium only a short distance

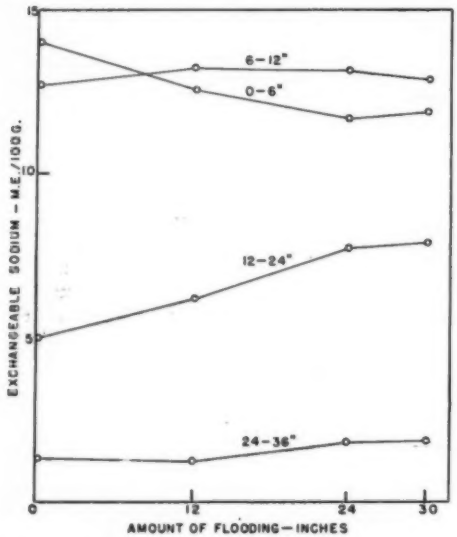

Figure 2.—Exchangeable sodium of four soil layers as affected by leaching (averages of four plots).

downward, where it was readsorbed in a zone of lower exchangeable-sodium-percentage. Thus the initial 12 inches of flooding, which reduced the exchangeable sodium in the surface six inches substantially, caused a marked increase in exchangeable sodium in the six-24 inch layer; and even after 24 inches of flooding, little, if any, sodium had been removed from the upper 36 inches of soil. Had the leaching operations been continued, sodium would eventually be moved beyond the 36-inch depth, but leaching efficiency in the surface layer would undoubtedly decrease as the soil reached a lower exchangeable-sodium-percentage. This is indicated by the leveling off of the curves in Figure 2.

Effect of Gypsum and Furrow Irrigation.—The soluble salt content of the surface layer of all plots increased during the cropping phase of 1950 (Figure 3). Those plots which had been leached in 1949 returned to a saline condition. Where gypsum had not been applied the increase was almost entirely in the surface six inches and reflected the normal upward movement of salts during the summer months. The gypsum-treated plots, however, increased in soluble salts throughout the three-foot sampling depth as a result of the sodium sulfate formed as a product of the reaction between calcium sulfate and the exchangeable sodium.

Gypsum caused a substantial decrease in soil pH (from 10.10 to 8.70 on gypsum plots and from 9.53 to 8.47 on leaching-plus-gypsum plots) in the surface six inches but had very little effect below that depth. In con-

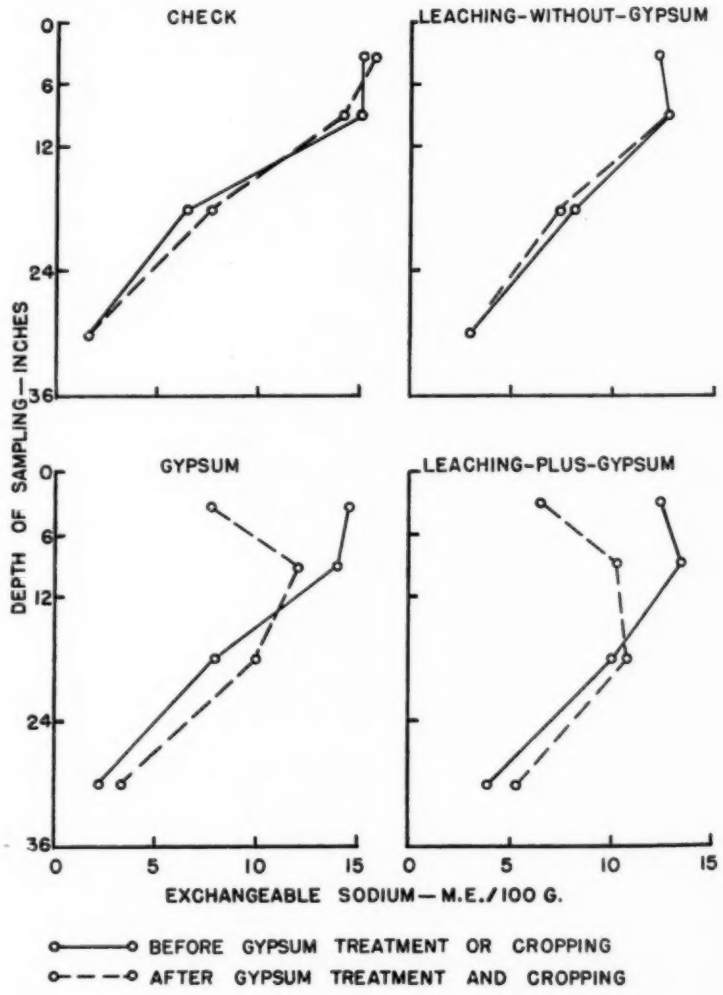

Figure 3.—Salt distribution at the beginning and finish of the cropping season (averages of four plots).

trast, over the same period, no pH change occurred in the plots where gypsum had not been applied.

On all gypsum-treated plots the exchangeable sodium content of the soil decreased (Figure 4), markedly in the surface six inches and to a smaller but significant extent in the six-12 inch layer. These decreases in

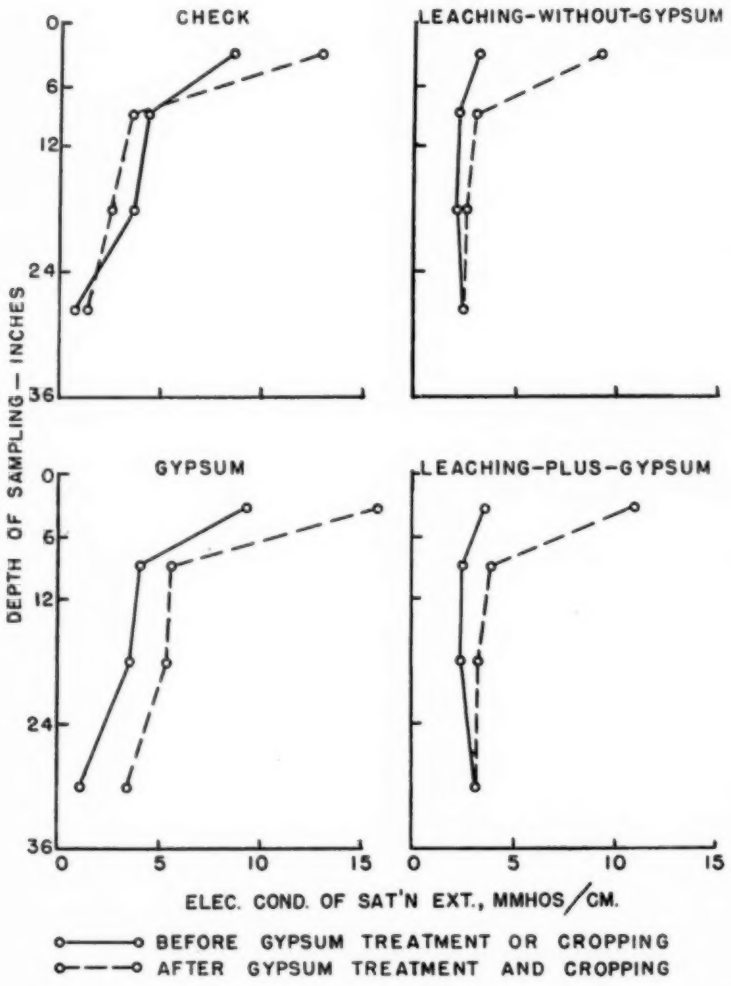

Figure 4.—Distribution of exchangeable sodium at the beginning and finish of the cropping season (averages of four plots).

the zero-six and six-12 inch layers were accompanied in every case by increases in the 12-24 and 24-36 inch depths. Thus the changes in exchangeable sodium were primarily redistribution within the upper three feet of soil and transformation from exchangeable to soluble forms. Data obtained during the study indicate that little if any of the sodium originally in the exchangeable form was moved below the three-foot depth. In comparison, there was no measurable change in the content of exchangeable sodium in any plots which did not receive gypsum (Figure 4).

The Effect of Leaching and Gypsum Treatments Upon the Stand and Yield of Sugar Beets

Table 1 gives the average stand counts and yield of beets as affected by the various treatments. Seedling emergence was greatly enhanced by

Table 1.—The Effect of Leaching and Gypsum Treatments upon the Stand and Yield of Sugar Beets[1]

Treatment	Beet Plants per 100 Ft. of Row			Yield
	Before Thinning	After Thinning	Harvested	Tons/Acre
No Treatment	222 ± 176	11 ± 5	1	Negligible
Leaching Without Gypsum	527 ± 186	51 ± 7	10 ± 3	Negligible
Gypsum	1009 ± 213	116 ± 9	98 ± 10	10.7 ± 1.2
Leaching Plus Gypsum	933 ± 29	113 ± 2	115 ± 2	18.0 ± 2.8

[1] Averages of four plots. The number following the ± is the standard deviation of the mean. Actual counts before and after thinning were on 144 feet of row. The count at harvest time was on 168 feet of row. Only beets over two inches in diameter are considered here.

the presence of gypsum, either with or without previous leaching, to the extent that plots with gypsum had approximately twice as many plants before thinning as did those with leaching only. Although the emergence of beets on plots receiving leaching but no gypsum was comparable to that on gypsum-treated plots, the soil condition was such that many of the plants had died by thinning time (Table 1) and only a few beets reached maturity. Gypsum not only increased the number of seedlings but also increased the vigor of the plants, with the result that wherever gypsum had been applied a good stand of beets remained until harvest.

Essentially no beets were harvested from plots not treated with gypsum, whereas all of the plots which had gypsum produced significant tonnages of beets. Of the two treatments which received gypsum, leaching-plus-gypsum was far superior to gypsum alone, the average yield of marketable beets for the two treatments being 18.0 tons per acre and 10.7 tons per acre respectively. This difference in yield was caused primarily by a difference in beet size rather than number. The weight of individual beets from the gypsum plots averaged only one and twelve one-hundredths pounds as compared with one and forty one-hundredths for the leaching-plus-gypsum treatment. As a consequence of their small size, a high percentage of the beets from the gypsum-treated plots were considered unmarketable (less than two inches in diameter). Figure 5 illustrates the marked effects of gypsum on the growth of sugar beets.

This study would indicate that leaching this soil without use of a

chemical amendment, applied either before or after leaching, would be an undesirable practice for the farmer to follow. Not only would the removal of exchangeable sodium be extremely slow, but also the soil dispersion which occurs following the removal of soluble salts would leave the soil too puddled for plants to grow. The factors limiting seed germination, seedling emergence, and subsequent growth of plants on saline-alkali soils are complex, as are the effects of gypsum in overcoming them. Both chemical and physical factors are involved. Gypsum may function in several ways. It provides calcium ions for the replacement of exchangeable sodium and for the formation of a more desirable calcium-sodium ratio in the soil, and reduces the dispersion and puddling which is usually associated with alkali soils.

Figure 5.—A view of a portion of the experimental field at harvest time: A. Leaching-plus-Gypsum, B. No Treatment, C. Gypsum alone, D. Leaching-without-Gypsum.

Summary and Conclusions

The effects of leaching and gypsum treatments on the reclamation of an unproductive saline-alkali soil (Umapine fine sandy loam) in the Yakima Valley of Washington were followed by periodic soil analysis and by measuring yields of sugar beets. The results can be summarized as follows:

1. The productivity of this saline-alkali soil can be raised from virtually nothing to reasonable levels by treatment with large quantities of gypsum. A satisfactory germination was observed on the check and leached plots but the beet seedlings failed to survive and no beets were harvested. On all gypsum-treated plots full stands of mature beets were obtained. The difference between the 10.7 tons per acre of beets obtained from plots treated with gypsum alone and the 18.0 tons per acre obtained from plots leached prior to treatment with gypsum was due to a greater average beet weight on the leached plots and is attributable to the removal of excess salinity by leaching.

2. Leaching without gypsum will effect some removal of exchangeable sodium but the rate of removal is too slow to be of practical significance. Once the soil salinity is reduced, penetration of water becomes extremely slow and an undesirable puddled surface structure develops.

3. The presence of gypsum greatly accelerates the removal of exchangeable sodium. Although plots leached prior to treatment with gypsum produced greater tonnages of beets than did those receiving only gypsum, their exchangeable sodium status at the end of the growing season was not substantially different. The beneficial effect of leaching on the yield of beets is due to removal of excess salinity. Treatment with gypsum followed by normal irrigation is far more effective in removing exchangeable sodium than is leaching through diked plots without gypsum.

4. Although the leaching and gypsum treatments greatly improved the soil condition and permitted a satisfactory crop of beets to be grown on certain plots, they did not fully reclaim the soil during the course of a single crop year. As the exchangeable sodium in the surface soil is reduced, there is an increase in exchangeable sodium in the subsoil. Removal of exchangeable sodium from the entire root zone is a slow process.

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Bed Planting of Sugar Beets

R. S. Lambdin and A. A. Armer[1]

Bed planting of sugar beets has been a common practice in some areas of California for many years. This system was developed by the vegetable growers because of their desire to do an exacting job of farming such speculative and perishable crops as lettuce, carrots, broccoli, etc. Poor irrigation, cultivation, or a partial stand cannot be tolerated, since they reduce quality and yield with consequent lower returns.

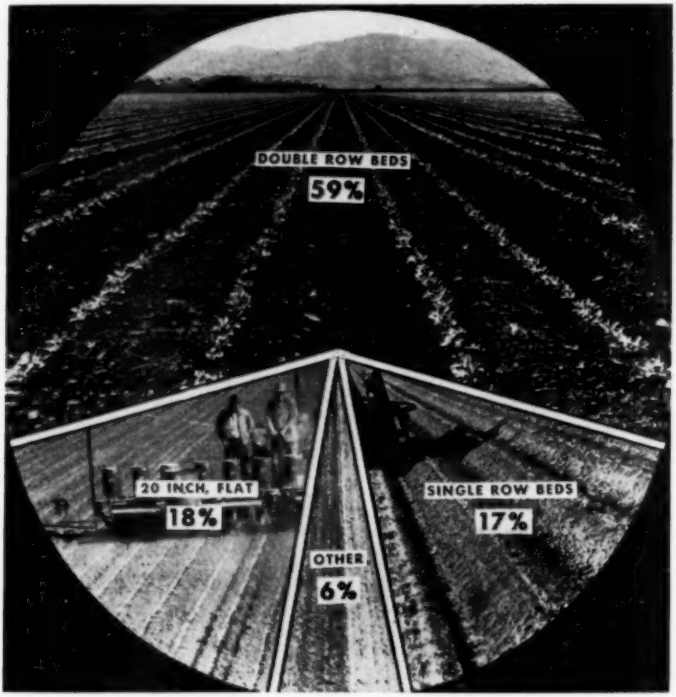

Figure 1.—Methods of planting beets in California areas.

Observation of the vegetable grower's success with bed plantings led the Spreckels Sugar Company to adapt this practice to sugar beet production approximately twenty years ago. The success of these early plantings gradually spread throughout the state and in 1951 75.7 percent of total beet acreage in California was planted on beds, either single or double row. (Figure 1).

Beds and row spacings vary in width from one district to another, depending upon the crops other than beets grown on the farm, the irrigation system, and the harvesting methods to be used.

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[1] Assistant District Manager and Agricultural Engineer, respectively, Spreckles Sugar Company.

Figure 2. The basic contour for sugar beet beds is made by ridging the field with lister shovels on 40 inch or 42 inch centers.

Figure 3.—Flattening the tops of beds and producing the final contour of the beds is accomplished with this bed-shaping tool.

An outline of the general cultural operations performed in order to do a satisfactory job of planting sugar beets on beds follows:

1. Fall plowing and deep chiselling in two directions with the second chiselling at right angles to the first. (This aerates the soil and provides sufficient loose soil for proper listing of uniform beds.)

Figure 4.—Irrigation for germination is standard practice with bed-planted beets. These small sheet metal dams control the flow of water when there is considerable slope to the field.

2. Harrowing, ring-rolling and floating, as necessary, to pulverize large clods.
3. Ridging the field with lister shovels, done with care in order to produce straight, uniform rows.
4. Shaping beds for planting with rollers, light harrows or bed shapers built specifically for this job. A bed shaper removes small weeds, levels the top of the bed uniformly and rebuilds the furrows.

Table 1.—Percent of California Sugar Beet Acres Planted on Various Row Spacings.

	Row Spacings					
	20" to 24"		26" to 34"		12"x28" to 16"x24"	
Districts in California	Flat	Beds	Flat	Beds	Flat	Beds
Sacramento and North San Juaquin Valleys	18.2%		1.8%	7.7%	3.7%	12.5%
Salinas, Santa Clara, San Benito, Santa Maria Valleys				0.1%		15.4%
South Coast, South San Juaquin and Imperial Valleys		.2%		9.0%	.6%	30.8%
% of State Aceage	18.2%	.2%	1.8%	16.8%	4.3%	58.7%

5. Planting, usually with four-row sled planters.

It is evident that cultural operations prior to planting are more complex if beds are to be used, but some very definite advantages can be derived in some of the beet growing districts.

Irrigation is the principal reason for planting beets on beds. It is possible to insure germination by introducing adequate moisture into the seed bed at planting time.

Beets can be properly irrigated at any time regardless of size, providing ample sub-moisture whenever needed.

During the wet season, small beets are kept well drained.

Large furrows help to reduce flooding which causes injury, particularly in heavy soils or in extremely hot weather.

Large heads of water can be used late in the growing season without danger of over-irrigation.

The Influence of Soil Structure on the Yield of Sugar Beets

H. Rietberg[1]

In the 1950 meeting of the American Society of Sugar Beet Technologists at Detroit the relation of soil structure to beet growth was discussed from a breeder's point of view. There are, however, many aspects of the soil structure problem connected with beet yield and, therefore, of economic importance to the farmer.

Although the major facts about soil structure have been known for a long time, our attention has been turned more particularly to this aspect of beet growing as a result of our work on the possibilities of mechanizing the beet crop in our country. We found soil structure problems closely connected both with spring and fall mechanization. Therefore, one of my collaborators, Mr. Jorritsma, in latter years has studied specifically the influence of soil structure in the various stages of beet growth and development.

In the Netherlands, more than 80 percent of the sugar beet crop is growing on silt and clay soils reclaimed from the sea. These soils can give good beet yields but they are difficult to handle in the spring. Here we met our first problem in spring mechanization. Especially when there is a period of dry weather in March or April, these soils dry very rapidly and form hard clods, so that much work has to be done to build a good seed bed. Enormous variations in emergence are the result. We, therefore, tried to study the relation between seed bed and emergence. For this purpose, we collected blocks cut out of seedbeds both of good and poor structure as they were prepared by farmers.

These blocks were cut out and transported in such a way that they remained in their original state and were all brought to Bergen op Zoom in our experimental garden. Here we planted them all with a certain number of seeds, both natural and rubbed, and studied the emergence without being hampered by differences in climatic conditions as would have been the case if we had collected these data in the original fields spread all over the country.

In these experiments in various years it has been found that the structure of the seed bed under our conditions has a very striking influence on seed emergence and first growth. The seedbed has to act as a "buffer medium" to regulate the influence of weather. If this "buffer medium" works satisfactorily the germination will be regular and reach a high final level, but when due to bad structure the seedbed suffers more from the variations in weather conditions, germination often is very irregular and comes to an end at a much lower level.

For our production this is very important. In the first place poor emergence will give a low plant population and under our conditions 400 plants per acre less means 1 percent less yield. Secondly, our work during

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20 years has shown the first eight-10 weeks of growth to be decisive for the final root yield. Therefore, it is very important that growth after emergence is continuous and not delayed or interrupted due to bad soil structure.

On our silt and clay soil, the ideal seedbed should have a top layer of about one inch of small crumbs and underneath a homogenous layer capable of holding sufficient moisture and quickly draining superfluous moisture. The farmer can do a lot to improve his seedbed by plowing carefully before winter and by superficial preparation in spring. However, when the season is late and the work is done in a hurry, these principles are very often forgotten.

The structure of the soil also has great influence on the shape and development of the root. The root of the beet is an ideal instrument for measuring soil structure as was proven by Dr. van den Berg, working on soils flooded with sea water during the war. Two years ago, I discussed this subject from the breeder's point of view, but from a farmer's point of view this problem is also important, at least with us, as our work has shown now a distinct negative correlation between early development of fangy roots and final yield. Therefore, on a soil of poor structure not only spring and autumn work are more difficult, plant population often too low and tare too high, but even with high dressings of fertilizers these fields will not give an optimum yield.

In addition to soil structure, the composition of the soil profile and soil pH influence root shape. Accumulation of unsatisfactorily decomposed manure and fresh green manure stimulates the development of fangy roots. Parasites like wireworm and fungi (blackroot) on the other hand cause forking of roots.

We also found in our experiments that as a general rule the sugar content of fangy roots is lower than in normal roots of good shape. Mechanical topping in these fields is more difficult, as with the development of sprangled roots there is a tendency to develop a larger crown growing out of the soil more irregularly.

The general picture is somewhat complicated since the reaction of all varieties is not the same. From an agricultural point of view, this problem is of such importance for us that in the description of sugar beet varieties given in the "Official List of Approved Varieties" we have entered also an estimate of the tendency of each variety to develop fangy roots.

Several pests and diseases influence the growth and development of sugar beets through soil structure. Often these reactions are very complicated and it is often not clear whether they are due to a stronger development of the parasite or weakening of the beet.

In our country, the incidence of blackroot is much stronger on soils of very labile structure, collapsing under heavy spring rains.

Wireworm attacks with us are very often connected with unfavorable soil structure and before H.C.H. products came on the market, farmers tried to combat wireworm by bringing air and warmth in the soil, i.e., by hoeing.

In fields with a low plant population or an open stand with many gaps, the development of virus yellows is stronger than in fields with a good population. Aphids have a preference for open stands and their rate of multiplication is much greater. Also, there is a possibility that in plants with a good continuous growth the development of the virus is slower, but for this we have no definite proof.

Sugar beets give their best yields on fields free of weeds. The tendency of some of our soils to develop compact layers at a certain depth is a great nuisance, for some very unpleasant weeds such as Equisetum, Agropyron and Tussilago thrive well on that type of soil. Some weed grasses germinate more easily in compact top layers while Cirsium maintains itself especially well in soils with a bricklike structure with horizontal and vertical cracks. Unfortunately, the relation between weeds and soil structure is not very well known.

In the factory the excessive tare on forked beets from soils of poor structure under wet conditions is a great problem. In the wet harvest season of 1950 in one of our factory areas, a dirt tare of 30-40 percent was considered as quite normal and the mudpumps were the bottleneck for factory capacity. Our factories claim that beets with sprangled roots give shorter cossettes and cause trouble in the diffusion batteries.

When growth has been slow on soils of poor structure, autumn rainfall can give a start to new top development combined with loss of sugar and increase of noxious nitrogen.

There are many other relations between soil structure and beets, but only a few have been mentioned. In the Netherlands, farmers are very interested in methods and means to improve soil structure. For the beet crop only a very conservative estimation has shown that, by improved soil structure, 15-18 dollars per acre per year, as an average, could be added to the farm income.

Effect of Type of Phosphate Material and Method of Application on Phosphate Uptake and Yield of Sugar Beets[1]

W. R. Schmehl, Sterling R. Olsen, and Robert Gardner[2]

The availability of various types of phosphate fertilizer to crop plants has been studied with new vigor since radioactive phosphorus has become avaliable as a research tool for field experimentation, and this research has contributed greatly to the knowledge of the availability of phosphate fertilizers in calcareous soils.

The national shortage of cheap supplies of raw sulfur, which caused the War Production Board to reduce superphosphate production in 1952 by 10 percent (1)[3], has stimulated investigations of phosphate fertilizers not requiring sulfuric acid which may be used as substitutes for superphosphate. There also has been a trend toward the increased sale of ammoniated phosphates which have not been adequately tested for calcareous soils. This paper reports the results of experiments conducted to determine the relative efficiency of various types of phosphate fertilizer materials and methods of application on calcareous soils of Colorado.

Materials and Methods

1950 experiment.—The experiment was conducted on Las Animas clay soil near Rocky Ford, Colorado, on one of the American Crystal Sugar Company farms. The soil contained approximately 7 percent $CaCO_3$ and 0.2 percent gypsum in the surface eight inches of soil.

The phosphate materials[4] used in the experiment were concentrated super phosphate, two ammoniated concentrated superphosphates (1.4 and 3.3 percent NH_3), and three calcium metaphosphates (minus 10, minus 40 and minus 100 mesh). The water solubility of the ammoniated phosphates was 80 and 67 percent for the low and high degrees of ammoniation, respectively.

Two methods of application were used for each phosphate material: 1) rototiller placement—the fertilizer was mixed with the soil in a band four inches wide and four inches deep and the seed was planted in the rototiller band; 2) concentrated band—the fertilizer was applied in a single concentrated band four inches deep and four inches to the side of the seed. The phosphorus was applied at 40 pounds P_2O_5 per acre and nitrogen was applied uniformly to all treatments at 60 pounds per acre. All fertilizer was added at the time of planting. The experiment was conducted as a factorial with three replications.

Radioactive phosphate fertilizer was applied in a small area in each plot, and beets grown in the radioactive area were sampled on May 22,

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[1] Joint contribution: Colorado Agricultural Experiment Station, Colorado A & M College, and U. S Department of Agriculture, Bureau of Plant Industry, Soils, and Agricultural Engineering. The work was supported in part by the Tennessee Valley Authority and the American Crystal Sugar Company. Authorized by the Director of the Colorado Agricultural Experiment Station for publication as Scientific Journal Series No. 384.

[2] Assistant Agronomist, Colorado Experiment Station; Soils Scientist, U. S. D. A. BPI, and Agronomist, Colorado Experiment Station, respectively.

[3] Numbers in parentheses refer to literature cited.

[4] The non-radioactive and radioactive phosphate fertilizers for the 1950 experiment were prepared by the division of fertilizer and agricultural lime and the division of soil management and irrigation, the Bureau of Plant Industry, Soils and Agricultural Engineering, Beltsville, Md. The radioactive fertilizers can be identified by the following lot numbers: concentrated superphosphate, No. 2787a; ammoniated concentrated superphosphates, Nos. 2788 and 2789; calcium metaphosphate, Nos. 2791a, 2791b and 2791c. The radioactive phosphorus was supplied by the Atomic Energy Commission.

June 19, August 1 and September 11. The plant material was analyzed for radioactive phosphorus according to methods of MacKenzie and Dean (3, 4).

1951 experiment.—The experiment was conducted on Fort Collins loam soil on the Agronomy farm near Fort Collins, Colorado. The soil contained approximately 3.5 percent $CaCO_3$ in the surface eight inches and was deficient in available phosphorus.

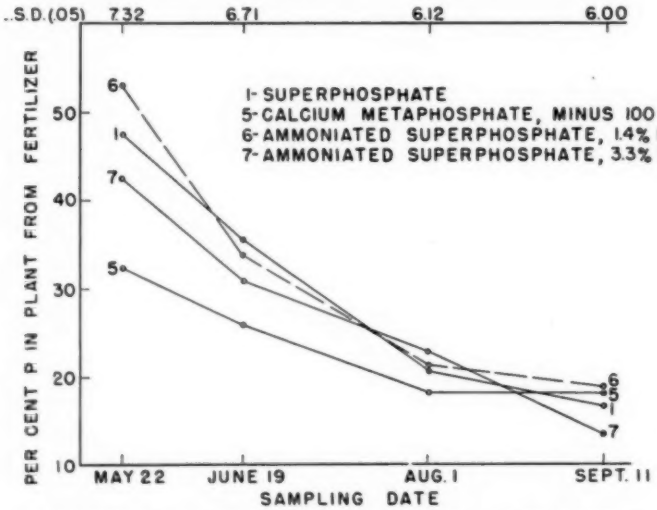

Figure 1.—Percentage of phosphorus in sugar beets derived from the fertilizer as affected by source of phosphorus.

The experiment was designed as a factorial with type of phosphate material and rate of application as variables. There were six replications. Phosphorus was applied at rates of 50 and 250 pounds P_2O_5 per acre. Nitrogen was added uniformly to all treatments. The phosphate materials[5] were concentrated superphosphate, two nitric phosphates (13-33-0), calcium metaphosphate (minus 40 mesh), and dicalcium phosphate (minus 40 mesh). The nitric phosphates were made by acidulating phosphate rock with a mixture of nitric and phosphoric acids. Processes for the manufacture of nitric phosphates are described by Hignett (2) and Rogers (6).

The fertilizer was broadcast and plowed under on March 17, and sugar beets were planted on April 13. No radioactive phosphorus was used in the 1951 experiment.

[5] The phosphate fertilizers for the 1951 experiment were manufactured and supplied by the Tennessee Valley Authority. The laboratory numbers of the fertilizers are: concentrated superphosphate, No. 11,304; nitric phosphates, Nos. 10,986 and 10,861; dicalcium phosphate, No. 8878; calcium metaphosphate, No. 65,653.

Results and Discussion

Effect of type of phosphate on the percentage of phosphorus in the plant derived from the fertilizer.—The results of the 1950 experiment are shown in Figures 1 and 2. The two ammoniated superphosphates supplied about the same amount of phosphorus to the plants throughout the season as did superphosphate. The plants absorbed more phosphorus from concentrated superphosphate than from calcium metaphosphate during the early part of the growing season, but absorbed about equal amounts from

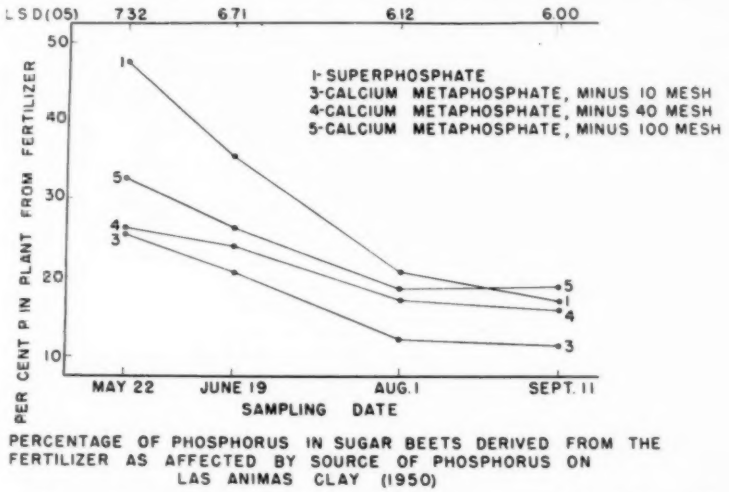

Figure 2.—Percentage of phosphorus in sugar beets derived from calcium metaphosphate as affected by particle size.

each material the latter part of the season. The results with calcium metaphosphate are similar to those reported by Olsen, et al. (5).

The absorption of phosphorus by the plants from calcium metaphosphate of different particle sizes (Figure 2) shows a consistent trend throughout the season for the absorption of the fertilizer phosphate to increase as the particle size decreases.

Effect of type of phosphate on the yield of beets and sugar.—The yields of sugar beets are shown in Table 1 for the 1950 experiment and in Table 2 for the 1951 experiment. There was no significant difference in yield between type of phosphate material in 1950, but the difference between the average yield of phosphated and non-phosphated treatments was significant at the five percent level. Inasmuch as only a slight phosphate deficiency existed in the field, the amount of phosphate supplied by the least available material apparently was sufficient to produce the maximum yield of sugar beets.

In the 1951 experiment (Table 2) the crop showed a response to all phosphate materials but the yield with dicalcium phosphate was significantly less than the average yield for the other phosphate treatments. Within the

limits of experimental error, the nitric phosphates, calcium metaphosphate and superphosphate performed equally well on this soil for sugar beets. The results show that there is an important difference between dicalcium phosphate and the nitric phosphates, although dicalcium phosphate is considered to be a major constituent of the nitric phosphates (2, 6).

The greater availability of calcium metaphosphate in the 1951 experiment as compared with the 1950 experiment or with the published results of Olsen, et al. (5), may be due to the difference in the method of application. The phosphate fertilizer was applied at the time of planting in the 1950 experiment and in the experiments of Olsen, et al. Even so, it was noted that the relative availability of superphosphate and calcium metaphosphate, as determined by radioactive tracer techniques, was nearly the same by mid-summer. In the 1951 experiment the fertilizer was plowed under 4 weeks before planting. The additional time of contact between fertilizer and soil may have increased the hydrolysis of the metaphosphate, thereby increasing the availability to the crop during the early part of the growing season and giving increased yields.

Statistical analysis of the data showed no interaction between phosphate material and rate of application. The increase in average yield for all materials due to the increase in rate of application was highly significant.

Table 1.—The Yield and Sugar Content of Beets as Affected by Type of Phosphate Material. 1950 Experiment, Las Animas Clay.

Type of phosphate	Sugar Content	Yield of beets (tons per acre)
	%	
Concentrated superphosphate	15.0	21.1
Calcium metaphosphate, minus 10 mesh	15.0	22.4
Calcium metaphosphate, minus 40 mesh	14.8	22.4
Calcium metaphosphate, minus 100 mesh	14.9	21.3
Ammoniated conc. superphosphate, 1.4% NH_3	15.2	21.1
Ammoniated conc. superphosphate, 3.3% NH_3	14.9	22.4
No phosphorus	15.1	20.0
Average, phosphated treatments	15.0	22.1[1]

[1] Significant increase at 5% level compared to no phosphorus treatment.

The sugar content of the beets was not greatly affected by applications of phosphate in the 1950 experiment (Table 1). In the 1951 experiment the sugar content of the no-phosphorus treatment was significantly less than the average for the phosphated treatments (Table 2), but there was no significant difference between phosphate materials. The average yield of sugar for the phosphate treatments was 3.32 tons in 1950 and 2.38 tons in 1951.

Effect of method of application of phosphate.—The fertilizer in the 1950 experiment was applied in a band and by mixing with the soil (rototiller placement). The uptake of fertilizer phosphorus as affected by method of application is given in Table 3. At the time of thinning (May 22) the uptake of phosphorus was greatest from fertilizer mixed with the soil, but at all later samplings phosphate uptake was greatest from the band application. The effect of method of application in this experiment was apparently largely a matter of positional availability. Fertilizer applied with the rototiller was highly available early in the season when a large portion of the root activity was in the rototilled zone of the soil, but later

Table 2.—The Yield and Sugar Content of Beets in the 1951 Experiment on Fort Collins Loam.

	50 lb. P_2O_5	250 lb. P_2O_5	Average[1]	Sugar Content
				%
Conc. superphosphate (47.6% P_2O_5)	13.8	15.9	14.8	15.8
Nitric phosphate (17-22-0)	14.7	15.4	15.5	16.0
Nitric phosphate (12-33-0)	15.4	15.7	15.5	16.0
Calcium metaphosphate, minus 40 mesh (62.9% P_2O_5)	15.7	15.4	15.5	16.0
Dicalcium phosphate, minus 40 mesh (46.0% P_2O_5)	12.7	14.8	13.7	15.7
No phosphorus	.....	.....	11.4	15.5
Average all phosphated treatments	14.5	15.4[2]	.....	15.9[3]
Average, all phosphated treatments except dicalcium phosphate	.....	.....	15.2[4]	.....

[1] L. S. D., phosphate materials; (.05) = 1.05, (.01) = 1.40.
[2] Significant increase at 1% level compared to 50 pound rate.
[3] Significant increase at 5% level compared to no phosphorus treatment.
[4] Significant increase at 1% level compared to dicalcium phosphate treatment.

in the season a smaller proportion of the root activity would be in the rototilled zone. On the other hand, although the plant roots would not contact the band-placed fertilizer as early in the season, root activity at a four-inch depth would be relatively greater the latter part of the season. Similar results have been reported for experiments on Fort Collins loam soil (5). Due to the lack of a phosphate deficiency in the soil, no yield differences between methods of application were noted.

Table 3.—The Percentage of Phosphorus in Sugar Beets Derived from the Fertilizer as Affected by Method of Application. 1950 Experiment, Las Animas Clay.

Method of application[1]	Percent of plant phosphorus derived from the fertilizer			
	May 22	June 19	Aug. 1	Sept. 11
Concenrated band	21.4	46.8	24.1	20.7
Rototiller	55.0	10.4	13.8	11.3
L. S. D. (.01)	5.9	5.3	3.6	3.8

[1] See text for description of method of application.

Summary

Concentrated superphosphate and two ammoniated concentrated superphosphates (1.4 and 3.3 percent ammonia) were equally available, within the limits of experimental accuracy, as shown by radioactive phosphorus studies. The availability of calcium metaphosphate to sugar beets increased as the particle size of the fertilizer decreased from minus 10 mesh, to minus 40 mesh, to minus 100 mesh. Calcium metaphosphate was not as available as concentrated superphosphate during the early part of the season when both materials were applied at the time of planting, but the two materials were about equally available the latter part of the season.

The yield of beets on a Fort Collins loam soil deficient in available phosphorus was about the same when concentrated superphosphate, calcium metaphosphate and two nitric phosphates were broadcast and plowed under four weeks before planting. The use of dicalcium phosphate fertilizer produced a yield increase over the no-phosphorus treatment but the yield was significantly below the average yield for the other phosphate fertilizers.

At the time of thinning, the uptake of phosphorus from fertilizer applied with a rototiller was greater than uptake from fertilizer placed in a concentrated band, but uptake of phosphorus was greater from the band-placed fertilizer for the remainder of the season.

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The Nitrogen Requirement of Sugar Beets[1]

JAY L. HADDOCK[2]

A decade ago the typical fertilizer recommended for sugar beets in the northern Great Plains and Intermountain areas was 6 to 10 tons of barnyard manure disked into the soil and 100 to 150 pounds of treble superphosphate broadcast before planting (9) (6)[3]. Such recommendations were based upon the results of field observations and experimental study.

Recent experiments by Tolman (10), Gardner and Robertson (3), Haddock and Kelley (4), and Swift (8) among others have emphasized the value of commercial nitrogen as a fertilizer constituent for sugar beets in addition to that supplied by crop residues and manure in these areas. These experimenters have noted also the harmful effects of excess available soil nitrogen on depressing the sucrose percentage of beets. Sugar beet yields and quality are so markedly influenced by available soil nitrogen (2) (11) (5) (3) that neither a deficiency nor large excess should be permitted where this crop is grown.

Nitrogen Required to Produce a Sugar Beet Crop

Since the nature of the sugar beet crop is such that its nitrogen requirement should be known and supplied with precision, one should first determine how much nitrogen a sugar beet crop requires. In most sugar beet growing areas a 20-ton crop of beets is frequently grown and 30 ton is an attainable goal.

How much nitrogen does a 20-ton crop of sugar beets need? Chemical analysis of both tops and roots at the Utah Agricultural Experiment Station indicates that such a crop removes from the soil approximately 200 pounds of nitrogen per acre. Since recovery of available plant nutrients from the soil is not complete, somewhat more than 200 pounds per acre must be made available in the soil. This is particularly true of nitrogen which is subject to heavy deep percolation losses under irrigation.

Adequate Nitrogen Fertilization

The intelligent sugar beet grower is anxious to know how much of the 200-pound nitrogen requirement his soil will supply and how much supplementary nitrogen he should provide. As stated by Brown (1), "The fertilizer application should depend upon the soil content of available plant food and the particular crop needs."

The present fertility status of most sugar beet soils necessitates the addition of only a fraction, but a highly important fraction, of the total nitrogen requirements for sugar beets, especially nitrogen, are rough and frequently soil test has been developed and standardized to provide an estimate of the seasonal nitrogen-supplying power of a soil. Recommendations on fertilizer requirements for sugar beets, especially nitrogen, are rough and frequently in serious error. Many beet growers and field men agree with the observations of Brown (1) who says:

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[1] Contribution from the Division of Soil Management and Irrigation, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture, incorporated with the Utah Agricultural Experiment Station, Logan, Utah.

[2] Soil Scientist, Division of Soil Management and Irrigation, Agriculture, U.S.D.A.

[3] Numbers in parentheses refer to literature cited.

> The farmers' cropping system, if he used clover crops in good rotation series have marked effects upon the fertility level and modify the fertilizer recommendations . . . We feel that much still remains to be done in persuading farmers to stop burning straw, to adopt better rotations and apply more fertilizer for this special cash crop. The general production can be raised much higher . . . if the proper fertilizer analyses are used in the proper quantities and put in the right place.

At the present time those charged with the responsibility of advising farmers do not have adequate facilities and information to direct wisely efficient nitrogen fertilizer practice. This fact is emphasized in the following statement by Walker et al (13):

> It might also be concluded that use of an average fertilizer requirement for the area, even if known accurately, could result in fairly frequent losses to the grower of as much as $50 per acre through missing the actual optimum for his particular field. Obviously, much of the difference in nitrogen requirement was caused by differences in fertility before the application of fertilizer.

Nitrogen Nutritional Status of Sugar Beets

How can the nitrogen fertilizer requirement be determined?

One obvious answer to this question is: by applying known graduated quantities of barnyard manure, green manure, crop residues and commercial nitrogen fertilizer, alone and in various combinations in carefully controlled field experiments, and observing the effects on yield and quality of crop.

This approach is generally thought to be too slow and expensive to be used on a wide scale. Various research workers have found approximate answers to this question. Robertson's (7) answer is to make current green tissue field tests for available nitrogen and side-dress the indicated fertilizer requirements. Gardner and Robertson (3) recommend the application of 10 to 15 ton of manure per acre. If manure is not available, maintain a comparatively high nitrogen level in the soil with commercial nitrogen even though a slight reduction in percentage of sugar may result.

Ulrich (12) suggests that chemical analysis of plant samples be made at regular intervals from the same field and used as a guide in adjusting the fertilizer program for succeeding beet crops. Walker et al (13) indicate that possibly the glutamic acid content of sugar beet roots may be the best guide to most efficient nitrogen applications. Brown (1) determines total and active organic matter in the soil and obtains the ratio A:T but does not indicate how this is used in fertilizer recommendations.

Experimental Results

A series of experiments was conducted at the Utah Agricultural Experiment Station in 1946, 1947 and 1948 in which some observations were made on the nitrogen requirement of sugar beets grown on typical soils of northern Utah. Some of the tests suggested above were applied to crops grown in order to have some basis for evaluating the effectiveness of the several treatments used.

The data presented in Table 1 show the effect of too little and too much nitrogen on the yield of beets, quality of beets and yield of gross sugar. It is not difficult to see that on soils with a nitrogen-supplying power sim-

ilar to these soils that 80 pounds of nitrogen increases yields of beets and gross sugar without decreasing sucrose percentage. There is evidence that the coefficient of apparent purity is decreased slightly. While an additinal 80 pounds of nitrogen further increased the yield in 1946, it simultaneously depressed the sucrose percentage to such an extent that gross sugar was not increased. In 1947 and 1948 yields were not increased by a second 80-pound nitrogen application. Although the yield of beets was not increased in 1948 the sucrose percentage and purity were markedly depressed, so that actually less sugar was produced from the additional nitrogen.

Table 1.—Yield of Sugar Beets, Sucrose Percentage and Sugar Production as Influenced by Nitrogen Fertilization.

Nitrogen Applied lbs./A	1946 Yield T/A	1946 Sucrose Percent	1946 Coeff. App. Purity	1946 Sugar T/A	1947 Yield T/A	1948 Yield T/A	1948 Sucrose Percent	1948 Coeff. App. Purity	1948 Sugar T/A
0	16.8	17.0	91.1	2.86	23.3	14.1	16.4	91.7	2.31
80	20.5	17.0	90.6	3.49	27.6	17.6	16.6	90.5	2.92
160	22.0	15.9	87.8	3.50	27.0	17.1	14.5	87.7	2.48
L.S.D. at .05	0.51	0.15	0.40	0.092	0.88	0.73	0.384	0.65	0.15

What effects from fertilizer application can be observed in the chemical composition of plant tissue? The data in Table 2 show that the nitrogen applied as fertilizer had a marked effect on the nitrate-nitrogen content of the beet petioles. It appears from these data that the nitrogen content in the plant should be kept above 1,000 ppm. until mid-September for best yields.

The relatively low nitrogen content of petioles in August and September of 1946 for the 80-pound nitrogen plots may be the answer as to why the 160-pound nitrogen plots gave still higher yields that year. It will be noted that high concentrations of soluble nitrates in beet petioles in October are associated with iow sucrose percentages and purity. It is easy to see from the data in Tables 1 and 2 the close relationship among nitrogen fertilization, yield, sucrose percentage, coefficient of apparent purity, yield of gross sugar and nitrate-nitrogen content of beet petioles.

Table 2.—Seasonal Nitrate-nitrogen Content of Sugarbeet Petioles as Influenced by Nitrogen Fertilization. (ppm)

Nitrogen Applied lbs./A	1946 July	1946 Aug.	1946 Sept.	1947 July	1947 Sept.	1947 Oct.	1948 July	1948 Sept.	1948 Oct.
0	1,122	294	112	2,660	534	42	6,750	123	320
80	1,972	500	88	14,800	1,136	276	8,500	1,291	280
160	2,317	2,336	1,140	15,750	2,362	1,719	9,300	5,300	1,440
L.S.D. at .05	243	116	92	1,913	496	714	1,621	1,916	540

It has been observed by sugar beet growers and research workers that frequently, when barnyard manure is applied in the spring of the year in which beets are grown, beet plants do not appear to obtain sufficient nitrogen for rapid growth until about August. This phenomenon was observed during the course of the experiments reported herein. This effect was not as

pronounced in 1948 as in 1946 and 1947. Only on those plots which received nitrogen fertilizer with or without manure did the beet plants appear to be adequately supplied with nitrogen during July and early August.

The data presented in Table 3 are typical of those obtained for other years. It will be seen that yields were increased in response to both nitrogen fertilizer and manure. Sucrose percentage was not affected by 80 pounds of nitrogen in presence or absence of manure. Fifteen tons of manure did not depress sucrose or purity. Eight pounds of nitrogen depressed purity slightly. One hundred sixty pounds of nitrogen with manure did not increase yields over the 80-pound nitrogen rate but this relatively high rate markedly depressed sucrose percentage, coefficient of apparent purity and gross sugar. It will be noted that the nitrate-nitrogen content of beet petioles

Table 3.—Influence of Manure and Nitrogen Fertilizer on Yield and Quality of Beets and Seasonal Nitrate-nitrogen Content of Petioles. (1948)

	Fert. Nitrogen lbs./A	Beets T/A	Sucrose Percent	Coeff. App. Purity	Gross Sugar T/A	Nitrate-nitrogen in petioles (ppm)				
						July 13	Aug. 2	Aug. 23	Sept. 18	Oct. 9
No Manure	0	13.03	16.42	92.12	2.09	5,460	2,580	530	130	240
	80	15.64	16.23	90.20	2.51	8,500	7,080	4,660	990	650
Manure 15 T/A	100	14.12	16.37	91.67	2.25	6,750	2,710	820	120	320
	80	17.63	16.56	90.47	2.92	8,500	9,600	5,080	1,290	280
	160	17.14	14.53	87.70	2.53	9,330	9,000	11,000	5,330	1,443
L.S.D. at .05		0.73	0.38	0.65	0.15	1,621	1,111	1,560	916	540

was similar regardless of manure treatment. Eighty and 160 pounds of nitrogen fertilizer had a pronounced influence on the nitrogen content of beet petioles.

These data do not establish 80 pounds as the most profitable rate of supplemental nitrogen on these soils. In 1946, 120 pounds of nitrogen may not have been too much. In 1947 and 1948, 40 pounds may have been sufficient for most efficient use of nitrogen. In order to obtain more detailed information on the effects of supplemental nitrogen on quality and yield of sugar beets, eight nitrogen fertilizer treatments were studied in 1948. The soil used had received 15 tons of manure, 80 pounds of nitrogen, 100 pounds of phosphoric acid and 60 pounds of potash per acre in 1947 previous to planting beets. Beet tops were left on the soil in the fall of 1947. Following this treatment it was not expected that a marked response for nitrogen fertilizer would result. The data in Table 4 show the effect of nitrogen supplement on the 1948 crop.

It will be observed in the second column of Table 4 that significant yield increases were obtained over unfertilized plots in all instances where 40 or more pounds of nitrogen were applied. Significant depressions in sucrose percentage and purity occurred where more than 80 pounds of nitrogen were applied. When 80 pounds of nitrogen were applied in a split application a similar depression occurred. A large excess of nitrogen gave no adverse affect on yield but sucrose percentage was so noticeably lowered that the highest rate of nitrogen tended to produce less sugar than was

obtained from untreated plots. The most profitable returns on this soil were obtained from 40 pounds of nitrogen. It is interesting to observe that yield, sucrose percentage and purity were not affected appreciably by an additional 40 pounds unless applied late in the season. It was definitely a waste of fertilizer to apply more than 40 pounds of nitrogen per acre and it was unprofitable to apply as little as 20 pounds.

It can be seen that when the nitrate-nitrogen content of beet petioles falls below 1,000 ppm. in August yields tend to be adversely affected. When more than 1,000 ppm. are present in petioles in October, quality is lowered. It appears as though the nitrate-nitrogen content of beet petioles should fall below 1,000 ppm. by mid-September. From August to harvest time the nitrate-nitrogen content of sugar beet petioles was roughly in the same order as the quantity of nitrogen fertilizer applied.

Table 4.—Yield and Quality of Sugar Beets and Seasonal Petiole Composition as Influenced by Nitrogen Fertilizer. (1948)

Nitrogen Applied lbs./A	Yield Beets T/A	Sucrose Percent	Coeff. App. Purity	Gross Sugar T/A	Nitrate-nitrogen in beet petioles (ppm)				
					7/13	8/2	8/23	9/18	10/9
0	17.61	16.72	92.27	2.94	4,725	2,975	962	220	132
20	18.87	16.75	90.63	3.16	6,850	5,550	947	238	36
40	19.73	16.39	91.35	3.23	8,100	9,850	2,230	224	48
80	19.69	16.28	90.54	3.21	8,200	10,650	3,581	232	456
80 ($\frac{1}{2}$ in Aug.)	20.10	14.93	88.37	3.00	8,100	9,850	3,370	2,740	1,536
160	19.79	15.15	87.09	3.00	8,850	13,100	9,775	1,780	792
160 ($\frac{1}{2}$ in Aug.)	21.57	13.25	83.97	2.86	8,200	10,650	4,925	5,830	2,476
320	19.45	12.96	83.93	2.52	8,850	15,300	14,050	4,790	1,848
L.S.D. at .05	1.72	0.83	1.29	N.S.	0,918	2,388	2,734	1,687	688

Discussion

It is evident from the data given here and from other work cited that either a deficiency or an excess of available soil and fertilizer nitrogen may have important economic consequences in sugar beet production. It is, therefore, important that a farmer know as precisely as possible the amount of nitrogen fertilizer he should apply to supplement other nitrogen available to his sugar beet crop.

The recommendations coming from various sources indicating ways of testing soils or plants as a basis for determining supplementary nitrogen requirements are helpful and serve an important need. However, it is difficult to see how plant tissue tests either on green or dry material can bring satisfaction to beet farmers generally. It is evident from the data presented herein that plant tissue analyses are useful in appraising the nutritional status of sugar beet plants. The effect of various field treatments on the uptake of nitrogen can be determined with confidence. Frequently, the information obtained from plant tissue analysis may be useful to commercial growers. But information on the nitrogen-supplying power of a soil would be much more useful to a sugar beet grower if it were available before planting time.

If a direct soil test could be developed which would supply sugar beet growers with a good estimate of supplemental nitrogen requirement, better yield and sucrose percentages would result. Furthermore, sugar beet growing would become more profitable. It would seem that greenhouse pot tests or soil incubation tests or a combination of these may have good possibilities.

Until some more useful measure of the nitrogen-supplying power of a soil is standardized, petiole analyses in conjunction with yield and quality data may be employed to furnish an approximation of supplemental nitrogen requirement. On the basis of such data presented above it appears as though 40 to 100 pounds of commercial nitrogen per acre should be applied on typical soils of northern Utah. Barnyard manure applied in the spring of the year in which beets are grown should be supplemented with commercial nitrogen.

What then is the nitrogen requirements of sugar beets?

The nitrogen requirement depends upon the season and the ability of a farmer to get the best growth of sugar beets by good farming practices. If a 20-ton per acre crop can be grown, the nitrogen requirement is approximately 200 pounds per acre. Of this total requirement the soil may supply from one-half to four-fifths or from 100 to 160 pounds of nitrogen per acre. The farmer should supplement this with 40 to 100 pounds of nitrogen fertilizer per acre.

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Sugar Beet Leaf Analysis Survey in Five Western States

F. S. FULLMER[1]

During the past 25 years plant analysis has become increasingly important in the study of nutritional problems. The present day approach to plant analysis is concerned with the nutritional status of the plant itself, while the earlier concept of its use as a biological method of soil analysis has been virtually abandoned. Soil tests, whether biological or chemical, attempt to simulate the ability of the plant roots to utilize the nutrient elements in the soil. The value of soil analysis should not be minimized, but it would seem logical to believe that the plant itself is the best judge of what is, or is not, available. The nutrient concentration in the plant is an integrated value of all outside influences, including the supplying power of the soil.

Time does not permit a discussion of the fundamentals involved in the use of foliar diagnosis, but a few elementary considerations should be mentioned. Sampling techniques, such as the portion of the plant, and the stage, or stages, of growth which most clearly reflect the nutrient level in the plant can be determined by means of controlled pot tests. A preliminary estimate of the "critical nutrient level" for any given element and crop may also be obtained by this method. The "critical nutrient level" might be defined as the concentration of the nutrient in the plant at which growth is restricted as compared to plants of a higher concentration. The establishment of "critical levels" for the various elements applicable to field conditions will result only from field fertilizer trials.

Numerous practical applications of plant analysis techniques have been made by research workers in the study of soil fertility problems. Some of these applications include:

1. **Nutrient absorption in fertilizer test plots.**

Fertilizer test plots have often shown "no response" due to the use of inadequate amounts, or improper placement of the materials being tested, and reflect the inability of the plant to utilize these elements, rather than the lack of a deficiency or deficiencies. A study of the nutrient levels in the plant will indicate whether or not the materials applied are being absorbed by the plant.

2. Identification of visual deficiency or toxicity symptoms.

Symptoms now associated with potassium deficiency of plums, grapes, tung, tomatoes, etc., were first suggested by analysis of plant material. This method was also used in identifying sodium excess symptoms on a number of deciduous fruits in California. Analysis of plant material also aid materially in distinguishing spray or insect injury from similar appearing deficiency symptoms.

3. Maintenance of soil fertility.

In tree crops, deficiencies found through the use of leaf analysis, or visual symptoms, can be corrected by appropriate fertilizer applications. However, in annual crops, such as sugar beets, the discovery of a deficiency by means of plant analysis does not insure that the condition can be profitably corrected in the current crop. In cases where the concentration of a

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nutrient is found to be deficient in the present crop, changes in the fertilizer practices on succeeding crops should be considered.

4. Leaf analysis surveys.

The use of a plant nutrient survey offers an excellent opportunity for the intelligent selection of sites for fertilizer test plots. An extensive survey covering a wide area or set of conditions will result in the location of the sections which are low in one or more of the three main nutrients These districts can then be sampled intensively, and fertilizer plots established on the fields which offer the best chance for response.

Sugar Beet Survey Procedure

From 1946 through 1950, approximately 1,500 sugar beet leaf samples were collected from 35 districts in Colorado, Montana, Wyoming, Idaho and Oregon. In most cases, two series of samples were collected from the same fields during the season, one at mid-season and the second at harvest time. The sampling and analytical techniques developed by Dr. Albert Ulrich, University of California, Berkeley, were followed in this work.

Table 1.—Mid-Season Samples.

	PPM NO_3-N	PPM PO_4-P	Percent K
Low	0-1,000	0-1,000	0-2.00
Medium	1,001-4,000	1,001-2,000	2.01-6.00
High	4,001 plus	2,001 plus	6.01 plus

The survey was conducted on an extensive basis, which means that one or two samples were collected, at each sampling time, from a number of low, medium and high producing fields in each district. Thus, the results represent the general fertility level in each of the districts sampled, rather than that of the individual fields. An intensive survey wherein a number of samples are collected from each field will be necessary before the nutrient status of individual fields can be determined.

Table 2.—Harvest Time Samples.

	PPM NO_3-N	PPM PO_4-P	Percent K
Low	0- 500	0- 500	0-2.00
Medium	501-2,000	501-1,500	2.01-4.00
High	2,001 plus	1,501 plus	4.00 plus

A sugar beet leaf analysis survey of the Arkansas Valley in Colorado was conducted in 1946 in cooperation with the Holly Sugar Company and American Crystal Sugar Company research and field staffs and the Agronomy Department of Colorado A & M. In 1947 samples were collected in the Utah-Idaho, Holly and Great Western Sugar Company territories of Montana and Wyoming. During 1948 and 1949 the work was confined to districts previously sampled, with the addition of a limited survey of the Amalgamated Sugar Company areas in Oregon and Idaho. In 1950, survey samples were obtained only from the Idaho and Oregon sugar beet growing sections.

Discussion of Results

In tabulating the data, a number of districts with the same general geographic location are included in each of the 7 regions listed. For example, there are 6 districts included in northern Montana, while eastern-southern Montana represents five districts. The percentage of samples which fall in each of the three nitrate, phosphate and potassium ranges is presented for both the mid-season and harvest time set of samples in Tables 1 and 2.

The "critical nutrient levels" of nitrates, phosphates and potassium have not been determined for sugar beets grown in the areas sampled. On the basis of past sugar beet leaf analysis work in California, the ranges listed in Tables 1 and 2 have been chosen as representing low, medium and high concentrations of nutrients at the two sampling periods.

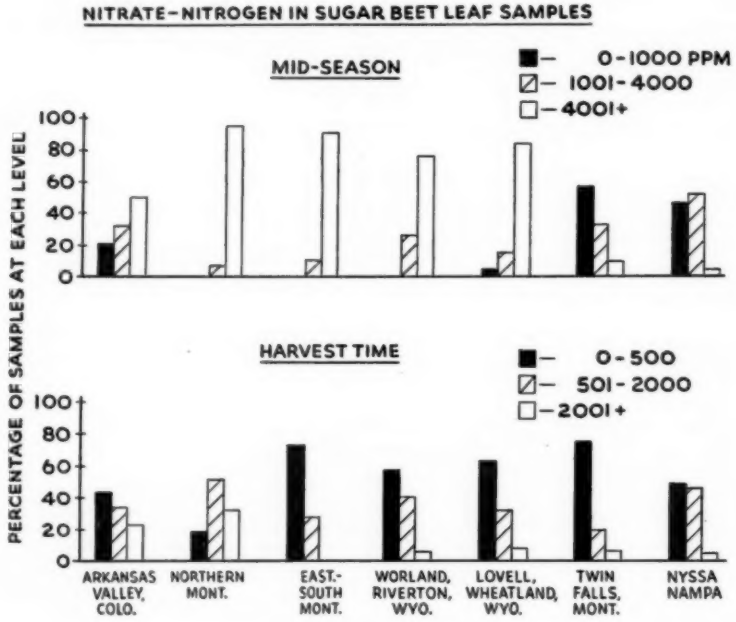

Figure 1.

Nitrate-Nitrogen Levels in Survey Samples

The nitrate-nitrogen results in Figure 1 show clearly that there is a wide variation in the concentration of this nutrient in the various regions sampled. Mid-season levels were lowest in the Twin Falls area with 57 percent of the samples falling below 1,001 ppm. NO_3-N, followed by Nyssa-Nampa with 45 percent and the Arkansas Valley with 20 percent. At this time, the fields sampled in both Montana and Wyoming appeared to be

adequately supplied with nitrogen. Judging only from the mid-season figures, there would be an excellent chance for a nitrogen response in half of the Twin Falls and Nyssa-Nampa fields, with little or no possibility of a response in either Montana or Wyoming.

The second series of samples indicated that the nitrogen supply in some of the areas, which had appeared to be ample at mid-season, had become exhausted by, or prior to, harvest time. This drop in nitrate levels was especially marked in the eastern-southern Montana and Wyoming districts. In these districts which had shown high mid-season concentrations, more than 50 percent of the samples contained less than 500 ppm. NO_3-N at harvest time. With the exception of northern Montana, the harvest time nitrate levels would suggest that fertilizer experiments, using nitrogen materials, would be justified in more than half of all the fields sampled.

The use of leaf analysis in test plot work and an accompanying survey of the surrounding area will be of immeasurable value in estimating the

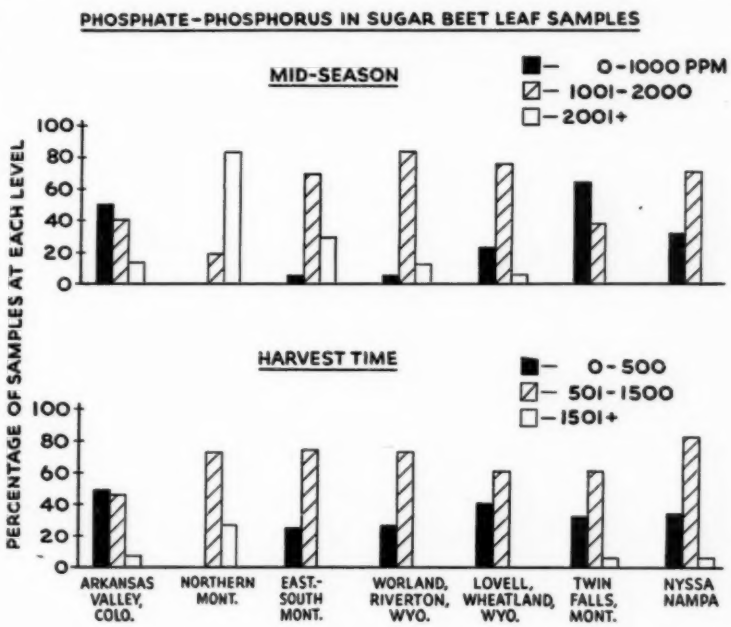

Figure 2.

percentage of fields represented by the test plot. For example, a fertilizer plot showing a nitrogen response at a mid-season leaf level of 1,000 ppm. NO_3-N would be representative of 57 percent of the fields in the Twin Falls area, and only 3 percent of the fields in the Lovell-Wheatland districts.

Phosphate-Phosphorus Levels in Survey Samples

As with nitrate-nitrogen concentrations shown in Figure 2, there were marked differences in the phosphate-phosphorus levels in the seven regions sampled. At mid-season, 63 percent of the samples from Twin Falls and 49 percent of the samples from the Arkansas Valley fell in the low range. The leaf levels indicated that phosphorus supplies were adequate, at this time, in the Montana and Worland-Riverton Wyoming districts.

The drop in phosphorus levels from mid-season to harvest time was most evident in the eastern-southern Montana and Wyoming areas. For example, 21 percent of the samples were below 1,001 ppm. PO_4-P at mid-season and 40 percent below 501 ppm. at harvest time at Lovell-Wheatland.

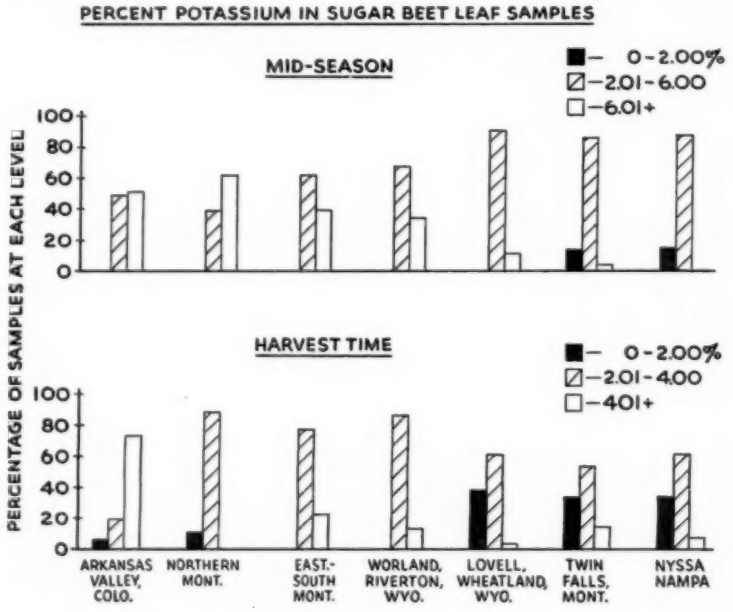

Figure 3.

The second series of samples from Idaho and Oregon is of special interest as the data indicate that the phosphorus-supplying power of the soil holds up late in the season.

The leaf survey data show that two distinct conditions occur in the phosphorus status of sugar beets grown in the areas sampled.

1. In some sections there is rapid depletion of the phosphorus reserves in the soil late in the season. The mid-season levels in the plant may or may not be low.

2. In other areas, with medium or low mid-season values, the decrease late in the season is slight.

Potassium Levels in Survey Samples

Past fertilizer test plots in the areas leaf sampled have suggested as shown in Figure 3 that the potassium-supplying power of the soils was adequate for the growing of sugar beets. The leaf concentration in most of the samples confirms the results of the past fertilizer tests. However, there are sections in which further potassium trials would be in order.

The only areas showing values of less than 2.00 percent K were in Oregon and Idaho. Approximately 12 percent of the samples were below this level at mid-season. Even in these areas, if the usual method of selection of sites for field plots was followed, there would be only one chance in ten that a field low potassium would be included.

The leaf levels of potassium dropped sharply late in the season in the Lovell-Wheatland districts, with 38 percent of the samples below 2.00 percent K at harvest time. At this time, about one-third of the fields were low in potassium in Idaho and Oregon, and the role of this nutrient should receive further attention in further fertilizer test plots in these areas.

Summary

1. The extensive sugar beet plant analysis survey demonstrated that there is a wide variation in the nitrogen, phosphorus and potassium concentrations in the seven regions sampled.

2. Intensive leaf analysis surveys could be used to advantage in the location of sites for future fertilizer test plots.

3. Further test plot and leaf analysis studies, using nitrogen and phosphorus fertilizers, would be justified in six of the seven regions sampled, while potassium may be a problem in three of the regions.

4. The use of leaf analysis techniques in conjunction with a thorough fertilizer test plot program will aid in determining more accurate "critical levels" for nitrogen, phosphorus and potassium.

5. As "critical nutrient levels" are established on various crops, it will be possible to predict the needs of succeeding crops by analyzing plant samples from the current crops.

Ten Years' Results from the Ferden Rotation and Crop Sequence Experiment[1]

L. S. Robertson, R. L. Cook, P. J. Rood and L. M. Turk[2]

The results of the first cycle of crop rotation and the field layout of the Ferden experiment were published in the 1946 Proceedings of the American Society of Sugar Beet Technologists. The experiment was started in 1940 for the purpose of obtaining answers to certain questions regarding soil management for sugar beets. It seemed particularly important to determine the role which legumes might play in the production of maximum yields. Seven cropping systems, involving three legumes, alfalfa, sweet clover and red clover, are arranged in such a way that all crops appear each year and plots are replicated four times.

All cropping systems are arranged as five-year rotations. Since the end of the first cycle of the rotations, brome grass has been seeded with the alfalfa and a mixture of alsike, June, mammoth and sweet clover was substituted for pure sweet clover as a green manure crop.

The soil where the experiment is located is classified as Brookston sandy clay loam. It contains 25 to 28 percent clay and 50 to 58 percent sand. The field is tiled but the structure of the soil is such that drainage is slow. The shape of the sugar beet roots indicates poor aeration during years of intensive spring rainfall.

The seven five-year rotations are as follows:

1. Barley, alfalfa-brome, alfalfa-brome, corn, beets.
2. Barley, alfalfa-brome, alfalfa-brome, beets, corn.
3. Barley, alfalfa-brome, alfalfa-brome, beans, beets.
4. Barley, oats, alfalfa-brome, corn, beets.
5. Barley, oats, red clover-timothy, corn, beets.
6. Barley, beans, wheat, corn, beets.
7. Barley-green manure, beans, wheat-green manure, corn, beets.
   (green manure is grown from alsike, June, mammoth and sweet clover seeded with barley and is plowed under the next spring for beans. The second crop of the same mixture is seeded in the spring on wheat and is plowed under the next spring for corn.)

All plots are divided into high and low fertility sub-plots. The high fertility sub-plots have received a total of 2,000 pounds of 2-16-8 fertilizer during the 10 years of the experiment. The low fertility sub-plots have received 800 pounds during that time. One-half of the fertilizer was applied at the time beets were planted. The remainder was applied to the grain crops.

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The reader is urged to refer to the first report (1)[3] on this experiment for details of plot technique and field lay-out.

Experimental Results

The second cycle of these rotations started with the 1946 season. Seedling loss due to black root resulted in failure of the sugar beet crop in 1947. The yields obtained during the other four seasons of the five year period are recorded in Table 1. The 1946 yields were high for that area. They

Table 1.—The Effect of Rotations at Two Levels of Fertilizer Application on the Yield of Sugar Beets.

Rotation[2]	Crop Sequence[1]	Yield Per Acre—tons									
		1946	1948	1949	1950	1941-45 Mean	1941-45 Diff in Mean	1946-50 Mean	1946-50 Diff in Mean	1941-50 Mean	1941-50 Rotation Mean
1H	Ba, A ,A, C, SB	11.7	12.68	8.99	11.15	10.34	1.66	11.13	1.99	10.70	9.78
1L		12.8	10.51	6.49	6.74	8.68		9.14		8.86	
2H	C, Ba, A, A, SB	17.1	8.33	8.32	8.08	10.88	1.72	10.44	2.22	10.69	9.72
2L		14.6	7.32	6.21	4.74	9.16		8.22		8.74	
3H	Ba, A,A, Be, SB	15.6	11.73	10.09	10.63	10.24	1.22	12.01	2.05	11.36	10.39
3L		14.1	10.83	6.75	8.14	9.02		9.96		9.42	
4H	Ba, O, A, C, SB	15.6	11.65	8.69	9.81	10.45	1.86	11.44	2.45	10.89	9.82
4L		13.1	9.96	5.67	7.21	8.59		8.99		8.77	
5H	Ba, O, Cl, C, SB	16.7	11.49	10.05	9.15	10.04	1.44	11.85	3.11	10.84	9.75
5L		12.4	9.29	7.13	6.14	8.60		8.74		8.66	
6H	Ba, Be, W, C, SB	11.7	9.72	8.77	8.81	9.64	1.71	9.75	1.51	9.69	8.88
6L		10.9	9.04	5.47	7.54	7.93		8.24		8.07	
7H	Bagm, Be, Wgm, C, SB	12.9	12.27	8.79	10.48	10.08	1.39	11.11	2.42	10.53	9.61
7L		11.5	8.96	6.23	8.08	8.69		8.69		8.69	
Significance Rotation[3]		*	**	.	*			**		**	**
L.S.D. 5%		2.56	1.81	1.37	1.76			1.8		0.59	0.59

[1] SB—sugar beets
C—corn
A—alfalfa-brome hay
Ba—barley
Be—beans
Cl—clover-timothy
W—wheat
Gm—green manure

[2] H—1,000 lbs. 2-16-8 per rotation
L— 400 lbs. 2-16-8 per rotation

[3] *—significant to 5% point
**—significant to 1% point

agree fairly well with the data obtained during the first cycle of the rotations. The highest yields were obtained where beets followed directly after two years of alfalfa-brome and the lowest were recorded from plots where beets followed corn in a rotation without a soil-building crop. By averaging the results from the high and low fertility sub-plots, the respective yields become 15.9 and 11.3 tons.

The second highest yields obtained in the 1946 season were from the plots where beets followed beans. This relative position of that rotation also agrees with the 1941-1945 results previously presented.

During the three years 1948, 1949 and 1950 sugar beets did not do well where they followed directly after alfalfa-brome. Comparing the results only from the sub-plots which received the heavier fertilizer applications, it is seen that the lowest yields in the experiment occurred on plots where that sequence was followed. Such was also true with respect to the yields from the low fertility sub-plots during 1948 and 1950. During the seasons 1943

[3] Numbers in parentheses refer to literature cited.

and 1945, beets did very poorly after alfalfa. The spring seasons of those two years were very wet. Planting was late in 1943 and the soil was worked wet.

It was suggested in the earlier publication (1) that beets do well after alfalfa when moisture and aeration conditions are favorable but do poorly in such a crop sequence during wet seasons when soils become puddled. It was further suggested that possibly a lack of soil air resulted in the accumulation of certain toxic decomposition products where fresh alfalfa had recently been turned under.

Smith and Cook (2) have shown by some greenhouse experiments that such a condition might occur. Now, the results from the last three years' studies lend further support to such a theory. When the last four years'

Table 2.—The Effect of Rotations on the Yield of Sugar Beets in the Greenhouse and in the Field.

Rotation	Crop Sequence	[1] Yield roots per pot or per acre Yield roots, percentage of top yield			
		Greenhouse		Field	
		grams	percent	tons	percent
1	Ba, A, A, C, SB	236	79	9.78	94
2	C, Ba, A, A, SB	234	78	9.72	94
3	Ba, A, A, Be, SB	299	100	10.39	100
4	Ba, O, A, C, SB	214	72	9.82	95
5	Ba, O, Cl, C, SB	187	63	9.75	94
6	Ba, Be, W, C, SB	149	50	8.88	85
7	Bagm, Be, Wgm, C. SB	202	68	9.61	92

[1] Greenhouse yields are averages of five crops, field yields are averages of nine.

results (the second cycle of the rotations) are averaged, rotation 2, where beets followed alfalfa-brome, becomes the poorest of all, except for number 6, the one without a soil building legume. It is interesting to note what has happened in rotation 3, where beets follow beans which follow the alfalfa-brome crop. Yields in that rotation, with both fertilizer levels, have considerably topped all the others. As the years have passed, evidence has continually pointed to the superiority of that sequence so far as sugar beets are concerned.

It is interesting at this point to present some supporting evidence from the greenhouse. In 1943 pots of soil were taken from the field plots to the greenhouse. During the next five years the same crops were grown in the pots as were grown in the corresponding field plots. The data recorded in Table 2 present a comparison between the five-year average pot yields and the nine-year average field plot yields. To make comparisons easier the yields are in each case reduced to a percentage basis with the highest yield taken as 100.

The highest yields in the pots were obtained where beets followed beans, as was the case in the field. In both greenhouse and field the lowest yields occurred where beets were grown in the rotation without a legume. Rotations 1 and 2 rank almost on an equal basis in both greenhouse and field.

These greenhouse results serve to support the evidence obtained in the field and the comparison is especially interesting to those who need proof

that greenhouse research may be very valuable when the work is properly conducted.

Reference to the last column in Table 1 shows that where sugar beets followed corn in rotation, where a legume had been plowed under for the corn, it made little difference what the legume was or how it was managed. As a nine-year average, the second highest yields were obtained where alfalfa-brome occupied the land during one year out of five, but yields almost as high occurred where the hay crop was left two years, as in rotation 1. Similar yields resulted where the legume was red clover hay or the clover-sweet clover green manure mixture. It should be remembered of course that, in rotation 7, two green manure crops were grown. A single green manure crop, handled as it is in this experiment, is probably not equal in soil building value to a hay crop of either clover or alfalfa.

Levels of Fertility

The mean yields reported in Table 1 show clearly that sugar beets are

Table 3.—The Effect of Rotation on the Sucrose Content of Sugar Beets.

Rotation	Crop Sequence	Percent Sucrose			
		1946	1948	1949	1950
1	Ba, A, A, C, SB	19.5	19.0	15.6	18.1
2	C, Ba, A, A, SB	19.0	17.5	15.8	16.9
3	Ba, A, A, Be, SB	20.0	19.0	15.9	17.7
4	Ba, O, A, C, SB	19.3	18.3	16.6	17.6
5	Ba, O, Cl, C, SB	19.7	18.6	16.9	17.7
6	Ba, Be, W, C, SB	19.8	18.8	17.1	17.8
7	Bagm, Be, Wgm, C, SB	19.7	19.2	16.9	18.1
Significance			**	*	
L. S. D. 5%		N.S.	.78	1.49	N.S.

very responsive to commercial fertilizer and that rates of application should be rather heavy. A comparison of the 1941-45 means with those for 1946-50 shows that, for all the rotations which include a legume, the response to the larger applications of fertilizer was greater during the second cycle of the rotations. This apparent increase in benefit from the fertilizer was greatest in rotations 5 and 7, those which included the clovers instead of alfalfa. Where there was no legume in the rotation there was a smaller response to the larger application of fertilizer as time progressed. In other words, as time passes it appears that fertilizers are becoming less effective in the soil-depleting rotation and more effective in those which include a soil building legume.

Sucrose Content

During the first cycle of these rotations, there was some indication that sugar beets grown after alfalfa contained less sucrose than those grown in a non-legume rotation or after sweet clover (1). In 1941 those grown directly after alfalfa contained significantly less sucrose than did those in any other rotation. It was thought, however, that the difference may have been the result of beet size. In 1945 there was some further indication that all the rotations which included two years of alfalfa had brought about reductions in percentage sucrose.

Beets grown after alfalfa in 1948 again contained significantly less sucrose than did those produced in the other rotations. The data presented in Table 3 show further that in 1949, as was the case in 1945, the beets from plots where alfalfa had been grown two years in the rotation were lower than those from any of the other plots. Perhaps it is safe to conclude that alfalfa has somewhat lowered sucrose percentages. The reduction, however, if real, has been very slight.

Rate of fertilizer application has affected sucrose percentages in only one year, 1949. During that year the heavily fertilized beets contained significantly more sugar than did those which were grown on the low fertility plots.

Table 4.—The Effect of Rotation at Two Levels of Fertilizer Application on the Yields of Corn.

Rotation	Crop Sequence	Yield Per Acre—bushels							
		1946	1947	1948	1949	1950	1946-50 Rotation Mean	1941-45 Rotation Mean	1941-50 Rotation Mean
1H	SB, Ba, A, A, C	57.2	52.7	48.8	99.0	63.5	63.7	44.7	54.2
1L		57.3	44.4	46.6	103.4	63.9			
2H	Ba, A, A, SB, C	55.8	32.6	60.1	87.3	58.5	59.7	39.1	49.2
2L		57.4	36.3	62.1	86.8	59.0			
4H	SB, Ba, O, A, C	66.5	48.1	50.0	98.8	63.0	64.6	45.5	55.0
4L		62.0	46.6	52.5	96.2	62.7			
5H	SB, Ba, O, Cl, C	60.0	44.4	33.3	94.7	62.9	59.1	42.3	50.7
5L		60.9	45.8	35.2	90.8	62.8			
6H	SB, Ba, Be, W, C	41.2	30.8	26.0	62.9	50.0	40.6	33.1	36.8
6L		46.0	29.9	20.3	59.7	38.8			
7H	SB, Bagm, Be, Wgm, C	57.4	37.3	42.7	86.2	56.0	56.6	39.5	48.0
7L		64.2	33.1	44.4	85.1	59.9			
Significance (rotations)		**	**	**	**	**	**	**	**
L. S. D. at 5%		7.41	5.43	10.97	12.91	8.71	3.96	2.77	2.77

Other Crops

Michigan sugar beet growers are interested in several other cash crops. Most important among these are corn, wheat and beans. It would be very unwise to adopt a soil management program for sugar beets without considering the requirements of the other crops. One might lose more on the other crops, by some certain practice or crop sequence, than was gained by greater beet yields.

Corn

In Michigan corn is very important to the beet grower because it is the only other row crop on many farms. That is especially true in the southern beet area where beans are not grown. Six of the rotations in this experiment include corn and in all except number 2, corn precedes sugar beets. The yields of corn, by years for the second cycle, are presented in Table 4. Also presented are the rotation means for the first and second cycles and for the ten-year period. The years 1949 and 1950 were especially good corn years. Averages for the period 1946 through 1950 were considerably greater than for the previous five-year period.

Corn yields have been consistently higher where a legume was included in the rotation than where only soil-depleting crops were grown. Statistical analyses have shown this to be true for the first five-year averages and for each of the last five years. The production of one year of alfalfa in the five-year rotation caused an average increase in corn yield of 12.4 bushels during the first five-year period. The average yields for the last five years show this figure to be increased to 24.0 bushels. Apparently the value of the alfalfa is building up as the years pass.

Yields of corn were not further increased by leaving alfalfa-brome for two years. In fact, the 10-year average yields of corn were slightly higher where the hay was left only one year. Where corn has followed clover-timothy, the crop has yielded 4.3 fewer bushels than where it followed one year of alfalfa-brome.

The sweet clover grown during the first cycle of the rotation caused a 6.4 bushel average increase in yield, whereas the green manure mixture used during the last five years caused an increase of 16 bushels. During that period the difference in the averages from rotations 5 and 7 was not sig-

Table 5.—The Effect of Rotation at Two Levels of Fertilizer Application on the Yield of Wheat.

Rotation	Crop Sequence	Yield Per Acre—bushels							
		1946	1947	1948	1949	1950	1946-50 Mean	1941-50 Mean	1941-50 Rotation Mean
6H	C, SB, Ba, Be, W	26.2	32.7	31.9	33.9	37.6	32.5	30.2	29.2
6L		24.7	31.5	27.3	32.9	34.8	30.2	28.1	
7H	C, SB, Bagm, Be, Wgm	25.8	37.8	35.5	38.6	42.7	36.1	33.9	33.2
7L		25.5	42.9	37.4	32.1	39.9	35.6	32.5	
Significance (Rotation)		—	—	—	—	—	**	**	
L. S. D. 5%							2.26	1.20	

nificant. In other words, the two green manure crops were about equal to one red clover-timothy hay crop.

In rotation 2, the crop sequence was such that beets followed alfalfa and corn followed the beets. As an average for ten years, corn yields were five bushels lower as a result of that sequence than where corn followed directly after two years of alfalfa-brome as in rotation 1. The sugar beet yield data (Table 1) show that sugar beets did not yield more where they followed the hay crop, so for the benefit of the corn it would seem well to recommend the use of rotation 1 in preference to rotation 2.

Levels of fertilizer application did not affect corn yields. This may have been partly due to the fact that the corn crop was not directly fertilized.

The question has often been asked "In what way does a soil building crop improve soil to result in increased yields of the following crops?" "Is it the result of nitrogen supplied by the legume or perhaps the result of improved soil structure brought about by higher organic matter levels?"

Certain studies not reported in this paper indicate that perhaps two-thirds of the yield increase attributed to the soil-building legume may be due to the nitrogen supplied by the decomposing residues. The remainder is probably the result of improved soil structure. Physical measurements

such as pore space and granule stability have shown that soil structure changes have resulted from the production of the soil building crops.

Wheat

Wheat follows beans in rotations 6 and 7. The only difference in the rotations is a green manure crop, consisting of a mixture of alsike, June, mammoth and sweet clovers, which is seeded twice in rotation 7. The data recorded in Table 5 show that the green manure crops increased wheat yields, as an average for ten years, by four bushels per acre. The wheat served as one of the companion crops for the green manure seeding, so the increase in yield was in spite of the competition offered by the clovers.

Yields of wheat were not appreciably higher on the plots which received the larger applications of fertilizer. This seems a bit strange because in other experiments the most economical rates of fertilizer have been much greater than the rate used on the low fertility side of these plots.

Table 6.—The Effect of Rotation at Two Levels of Fertilizer Application on the Yield of Beans.

Rotation	Crop Sequence	Yield Per Acre—bushels							
		1946	1947	1948	1949	1950	1946-50 Mean	1941-45 Mean	1941-50 Rotation Mean
3H	SB, Ba, A, A, Be	20.5	18.8	21.0	34.6	27.4	24.5	20.5	20.5
3L		19.4	16.2	20.3	32.2	26.7	23.0	19.6	
6H	W, C, SB, Ba, Be	17.1	10.8	19.1	31.0	22.0	20.0	17.1	16.5
6L		14.6	8.7	17.2	28.1	22.8	18.3	15.8	
7H	Wgm, C, SB, Bagm, Be	19.2	9.9	21.9	33.6	23.9	21.7	18.3	17.8
7L		16.5	6.2	18.2	31.8	21.6	18.9	17.3	
Significance (rotation)		—	**	—	—	*	**	**	**
L. S. D. at 5%		4.17	2.55	5.27	6.47	3.50	1.75	1.16	1.16

White Beans

In the Saginaw Valley and Thumb areas, most beet growers include beans in their rotation. This experiment has shown the desirability of growing beets after beans and the importance to the beet crop of a legume in the rotation, so it is well to see what effect the legume has on the beans. The crop occurs after alfalfa-brome in rotation 3 where the ten-year average yield has been 20.5 bushels an acre, four bushels more than that from the rotation where legumes are not grown. So, to the value of the alfalfa-brome in rotation 3 there should be added the value of one and fifty-one one hundredths tons of beets and four bushels of beans. If one adds still further the value of about four bushels of barley which followed the beets, the alfalfa-brome crop becomes a very valuable part of the rotation.

The mixed clover green manure caused a smaller but statistically significant increase in bean yields. Apparently alfalfa-brome is a much better soil building crop for beans than is the clover mixture. Perhaps the grass plays some role in this difference in response.

Heavier applications of fertilizer did have some effect on beans. The heavily fertilized plots averaged about one more bushel an acre than did those which received the lighter application. Over a ten-year period that difference may be significant. The loan data are reported in Table 6.

Summary

A crop rotation and sequence experiment was started in 1940 on Brookston sandy clay loam on the Ferden farm in Saginaw County, Michigan. The study was designed especially to determine the effects of other crops, including legumes and grasses, on the sugar beet crop. Seven five-year cropping systems are being studied. The details of the layout and experimental methods and the first five years' results were presented at the 1946 meeting of the American Society of Sugar Beet Technologists, and were published in the Proceedings of the Society.

The second cycle of this experiment was completed in 1950. The value of soil-building crops was more evident than during the first cycle. The highest beet yields were obtained in the rotation where the crop followed beans which in turn followed two years of alfalfa-brome hay. Lowest yields were obtained where there was no legume in the rotation.

At the end of the first cycle of the rotations, the highest average beet yields were from plots where beets had directly followed alfalfa. During that period, however, there were two years when that rotation did not show up so well. Rainfall was excessive during the growing season of both of those years. The second cycle of the experiment also included several years of high rainfall and the beets which followed alfalfa produced very low yields. As a result the averages for both rotation cycles show that beets directly after alfalfa did not do so well as they did after beans and no better than after corn.

Considering nine-year averages, it made very little difference, so far as beet yields were concerned, what legume was included in the rotation. One year of alfalfa-brome was as good as two and red clover-timothy proved to be almost as good. The two mixed clover green manure crops were just equal to the red clover-timothy hay crop.

Corn and bean yields were markedly increased by the production of legumes in the rotation. They were highest where the crop followed alfalfa-brome. The mixed clover green manure greatly increased corn yields and caused considerable increase in wheat and bean yields. Still higher corn yields resulted where red clover-timothy was grown in the rotation but that rotation was inferior to the one which included alfalfa-brome. As with sugar beets, yields of corn were not increased by leaving the hay for more than one harvest year.

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The Responses of Sugar Beets to Fertilizers, Spacing, and Irrigation on Eastern Oregon Soils[1]

ALBERT S. HUNTER AND JOHN A. YUNGEN[2]

An intensive program of soil fertility research was initiated in 1950 on the irrigated soils of Malheur County, Oregon. The objectives of this program are to determine (A) the fertility status of the soils and the fertilizer and soil moisture needs of the crops in that area, and (B) the correlation between the field responses to fertilizer applications and laboratory soil test data. Some 35 field plot experiments have been carried out under this program during the 1950-51 seasons. Of these, 15 were with sugar beets.

Experimental Materials and Methods

All sugar beet experiments were carried out on the fields of cooperating farmers, who prepared seedbeds, planted, cultivated and irrigated (except one experiment, where irrigation was a variable) the beets according to their own schedules. Application of fertilizers, thinning and harvesting of beets were performed under direction of the authors. Fertilizers, plot stakes, thinning and harvesting labor, a portable rasp and other sampling equipment were supplied by the Amalgamated Sugar Company[3]; the Company also made sugar analyses on samples from all plots.

A belt-type, tractor-mounted fertilizer distributor with double-disk furrow openers (3)[4] was employed to band-place fertilizers two to four inches from the row and one and one-half to three inches deep. Fertilizers were applied soon after planting, usually within two to four days. With one exception, fields were not irrigated until thinning time.

Ten experiments on sugar beets (48 plots each on six farms, 96 plots each on three farms, 198 plots on one farm) were conducted in 1950, five (48 plots on each of three farms, 56 plots on one farm, 90 plots on one farm) in 1951. Sites were widely scattered over the beet-growing area of the county. Plots were 30 feet long and six, or eight, rows wide. Row spacings were 16-24 (two farms), 18-24 (one farm), 20 (three farms), 20-22 (two farms), 21 (two farms), and 22 inches (five farms). At 13 sites the following fertilizer treatments (N-P_2O_5-K_2O per acre, from ammonium sulfate, treble superphosphate, and muriate of potash) were replicated four times in randomized blocks:

(1)	0-0-0	(4)	150-0-0	(7)	0-80-0	(10)	150-80-0
(2)	50-0-0	(5)	200-0-0[5]	(8)	50-80-0	(11)	200-80-0
(3)	100-0-0	(6)	0-40-0	(9)	100-80-0	(12)	100-80-80
						(13)	100-80-160[6]

These treatments represent 4 N (or 5 N) x 2 P_2O_5 factorial combinations, with additional treatments. Two rates of stand were factorially combined with the above in three experiments.

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[4] Numbers in parentheses refer to literature cited.

[5] Included in 4 experiments in 1951, omitted 1950.

[6] Included in 9 experiments in 1950, omitted in 1951.

At one site in 1950 the above treatments 4, 5, 6, and 13 were omitted; to the nine remaining, two treatments, 50-40-0 and 20 tons manure, were added. Three irrigation treatments were factorially combined (six replications) with the 11 fertility treatments. To study the effects of N level and irrigation treatment on uptake of P_2O_5, radiophosphorus was applied in treatments 7 and 9. The effects of time and method of application of factorial combinations (three replications) of 0, 50, and 100 pounds of N and 0 and 100 pounds of P_5O_2 per acre were studied at one site in 1951.

At harvest the beets from the four center rows from each plot were lifted, topped, counted and weighed. A tare sample of 10 beets was randomly selected from each plot. Pulp from these 10 beets was then rasp-sampled for sugar analysis; these samples were frozen to prevent deterioration. The data from each site were subjected to analysis of variance. The significance of N and P_2O_5 effects was determined for the factorial portions of each experiment.

Table 1.—Significance of Effects of N on Sugar Beets.

No. Farms	Effects of N on		
	Yield T./A.	Percent Sugar	Sugar, Lbs./A.
4	Sig.[1]	Sig.[2]	Sig.
4	Sig.	N.S.	Sig.
1	Sig.	Sig.	N.S.
3	N.S.	Sig.	N.S.
1	N.S.	Sig.	Sig.[3]
2	N.S.	N.S.	N.S.

[1] Sig. = significant at P = 0.05. N.S. = not significant.
[2] Increase on one farm.
[3] Decrease.

In 1950 composite samples of the soil from each replication of each experimental site were obtained from the 0-6, 6-12, and 12-24-inch depths; in 1951 the depths were changed to 0-8, 8-16, and 16-24 inches. Samples were analyzed for pH, organic matter, total N, nitrifiable-N (2), exchange capacity, exchangeable Na and K, (1), water soluble (4) and CO_2-soluble (5) PO_4, and conductivity of saturation extract.[7]

Results and Discussion

Effects of Fertilizers

Statistically significant (P = 0.05) effects of N were observed on a total of 12 farms. Significant effects of P_2O_5 were produced on only one farm. No significant effects of K_2O were found.

A summary of the significance of the effects of N is presented in Table 1. Yield of beets, percent sugar and yield of sugar were each affected significantly by N on nine farms.

Increases in yield of beets and sugar (decrease in sugar yield in one case) and decreases in percent sugar (increase in one case) were associated with significant effects of N. On eight of the nine farms where N significantly increased the yield of beets the yield of sugar was also significantly increased, even though on four of these farms the percentage of sugar was significantly lowered. On one farm the yield of beets was increased, but

[7] All statistical analyses were performed under supervision of Dr. Jerome C. R. Li, Assoc. Prof. of mathematics, Oregon State College.

sugar content was reduced, with the result that the yield of sugar was unaffected. On one farm the yield was not affected significantly but the percentage of sugar was lowered sufficiently to result in a significant decrease in sugar yield. On three farms the yield of beets and sugar were not affected by N, although the percentage of sugar was lowered. On three farms N had no significant effects.

In Table 2 are set forth summaries of the average effects of N, P_2O_5 and K_2O on yield of beets, percent sugar, and yield of sugar. Data on effects of N are presented separately for the two years because of large differences in average yield.

The yield of beets was increased by N on six farms in 1950 and three farms in 1951. In 1950 the average increases from 50, 100, 150 and 200 pounds of N were 2.4, 4.1, 5.3 and 5.8 tons, respectively. (The last value is an average from only five farms and hence not strictly comparable with the first four values.) In 1951, on three farms, average increases of 2.4 and 4.7 tons, respectively, were obtained with 50 and 100 pounds of N. Five rates of N were employed on only two of the three farms; the average increase on these two farms was 2.1, 4.4, 5.3 and 5.0 tons for 50, 100, 150 and 200 pounds of N, respectively. Effects of N on yield of beets were not significant on four farms in 1950 and two farms in 1951. In both years the group of farms not giving significant response averaged considerably higher in yield than the responsive group.

The sugar content decreased with increasing N on five farms in 1950 and three farms in 1951; on one farm in 1950 percent sugar was significantly increased by N. The decrease from 100 pounds of N per acre ranged between 0.2 and 1.1 percent and averaged 0.3 percent in 1950 and 0.4 percent in 1951. The application of 200 pounds of N lowered the sugar content by about 1.1 percent each year, in comparison with no N. Effects of N on percent sugar were not significant on four farms in 1950 and two farms in 1951.

On six farms in 1950 and two farms in 1951 the yield of sugar was significantly increased by N; on one farm in 1950 the sugar yield was significantly lowered. (On this farm, although effects of N on yield were not significant, yield of beets tended to decrease with increasing N. Percent sugar was decreased by N). As an average of the seven farms in 1950 and two farms in 1951 on which N produced significant effects the yield of sugar increased substantially with N, up to 100 pounds of N per acre. On no farm, however, did 150 or 200 pounds of N significantly increase the yield of sugar over that obtained with 100 pounds of N. On three farms in each year the yield of sugar was not affected by N.

A significant increase in yield of beets and sugar was produced by P_2O_5 on only one farm in 1950. The yield was increased from 13.3 to 19.6 tons per acre by 80 pounds of P_2O_5. (On this farm the phosphated plots had significantly greater number of beets per plot than the non-phosphated plots, averaging 14.2 inches apart in the row, against 17.7 inches, owing to the fact that the more vigorous beets on the phosphated plots were better able, when small, to withstand attacks of wireworms which killed or damaged numerous plants on the non-phosphated plots. On this field, therefore, the effects of P_2O_5 were partially secondary in nature). On 14 farms P_2O_5 had no significant effects.

Applications of 0, 80 and 160 pounds of K_2O per acre were made in 1950 on 10 farms; 0 and 80 pounds were applied on four farms in 1951. In each case the application was made with 100 pounds of N and 80 pounds of P_2O_5. In no case was a significant response observed.

Table 2.—Summary of Effects of Fertilizers on Sugar Beets.

Fertilizer Treatment	Yield, Tons/A.		Percent Sugar		Lbs. Sugar/A.	
Effects of N on 10 farms in 1950 Averages for N with 0 and 80 lbs. P_2O_5/A.[1]						
N, Lbs./A.	6 Farms Sig.	4 Farms N.S.	6 Farms Sig.	4 Farms N.S.	6 Farms Sig.	4 Farms N.S.
0	16.7	23.3	16.1	15.5	5,640	7,150
50	19.1	24.3	15.9	15.5	6,210	7,670
100	20.8	24.3	15.8	15.5	6,610	7,580
150[1]	22.0	24.1	15.1	15.2	6,720	7,290
200	22.5	23.5	15.1	14.9	6,870	6,910
Effects of N on 5 farms in 1951 Averages for N with 0 and 80 lbs. P_2O_5/A.						
N, Lbs./A.	3 Farms[2] Sig.	2 Farms N.S.	3 Farms Sig.	2 Farms N.S.	2 Farms Sig.	3 Farms N.S.
0	24.3	28.1	17.0	17.3	8,390	8,330
50	26.7	28.1	16.8	17.1	9,010	9,200
100	29.0	29.6	16.6	17.1	10,020	9,700
150	33.6[2]	30.6	16.2	16.5	12,720	9,710
200	33.3	29.9	15.9	16.9	12,110	9,500
Effects of P_2O_5 on 15 farms, 1950-51 Averages for P_2O_5 with 0, 50, 100, 150, and 200 lbs. N/A.						
P_2O_5 Lbs./A.	1 Farm Sig.	14 Farms N.S.		15 Farms N.S.	1 Farm Sig.	14 Farms N.S.
0	13.3	24.0		16.0	4,520	7,560
80	19.6	24.2		16.0	6,820	7,690
Effects of K_2O on 14 farms[3], 1950-51						
N-P_2O_5-K_2O, Lbs./A.	10 Farms 1950	4 Farms 1951	10 Farms 1950	4 Farms 1951	10 Farms 1950	4 Farms 1951
100-80-0	22.4	31.5	15.5	16.5	6,920	10,510
100-80-80	22.5	31.0	15.5	16.7	6,910	10,260
100-80-80	22.1		15.6		6,890	

[1] 150 pounds of N were applied on only five of the six farms giving significant yield responses to N in 1950. On these same five farms 200 pounds N were applied only with 80 pounds P_2O_5. For these reasons, averages for the three lower and two higher rates of N are not strictly comparable.

[2] One farm received N only at the 0-, 50-, 100-pound rates. The averages for 0, 50 and 100 pounds N respectively for the two farms where 150 and 200 pounds N were applied were 28.3, 30.4 and 32.7 tons; averages for percent sugar were 17.2, 17.0 and 16.8.

[3] On one farm no K_2O was applied.

Effects of Spacing

Spacing within the row was a variable, in factorial combination with 12 fertilizer treatments, on three farms in 1950. Distances between rows were 16-24, 21 and 22 inches. Care was taken to initially thin the beets to spacings averaging 12 and 15 inches apart in the row. At harvest time the spacings on the three farms averaged 12.3 and 15.8, 12.6 and 15.7, and

13.6 and 16.2 inches, respectively, for the two rates of stand. Average yields for 48 plots of each of the two spacings were, respectively, for the three farms, 26.3 and 26.7, 23.8 and 22.4, and 19.5 and 18.3 tons of beets per acre. On the latter farm the difference was statistically significant, and 13.6-inch spacings outyielded the 16.2-inch spacings by one and two-tents tons per acre. On two out of three farms the wider spacing produced a significantly lower yield of sugar than the closer spacing. Effects on percent sugar were not significant.

Effects of Irrigation

Irrigation was a variable in one experiment. Three irrigation treatments were factorially combined with 11 fertility treatments. In these irrigation treatments the soil was irrigated thoroughout the season (beginning with a uniform irrigation on April 21, for germination, and on May 28, following thinning) when (M_1) the soil moisture tension of the 100-80-0 plots reached 750 cms. at the eight-inch depth, as indicated by tensiometers (10 irrigations), (M_2) the resistance of Bouyoucos and Mick gypsum blocks at the eight-inch depth of the 100-80-0 plots reached 100,000 ohms (five irrigations), and (M_3) as in M_1 until August 12, then irrigated no more (seven irrigations).

Table 3.—Effects of Irrigation Treatments on Sugar Beets[1].

	Irrigation Treatment			
	M_1	M_2	M_3	L.S.D. (0.05)
Yield, tons/A.	18.6	20.1	16.9	0.80
Percent sugar	17.2	16.4	17.9	0.15
Sugar, lbs./A.	6,500	6,600	6,060	275
Spacing in row, ins.	15.5	14.7	15.4	0.35
Wt./beet, lbs.	2.05	2.07	1.82	

[1] Each value is the average for 6 replications of 11 fertilizer treatments, or 66 plots.

The effects of irrigation treatment are summarized in Table 3. In the M_1 treatment the plots were irrigated on June 21, July 5, 14 and 24; August 1, 12 and 21, and September 1 and 16. Irrigations of the M_2 plots occurred on June 21, July 24, August 16 and September 23. The greatest yield of beets was produced by the M_2 treatment. Plots of this treatment also had more beets at harvest time than the M_1 and M_3 plots, although original spacing was uniform (approximately 12 inches).

The beets in this experiment were attacked by wireworms very shortly after emergence. The higher moisture levels maintained in treatments M_1 and M_3 evidently favored destruction of the beets by wireworms and pathogenic organisms to a greater degree than the lower moisture levels of the M_2 plots. The average weight of beets in M_1 and M_2 plots was almost identical, indicating that differences in numbers of beets per plot were responsible for differences in yield. The M_1 and M_3 plots had similar spacing, but the yield of beets and sugar from the M_3 plots were significantly lower than those of the other treatments, although the sugar percentage was higher.

Effects of N Levels and Irrigation Treatment on Uptake of P_2O_5

To study the effects of variation in N and soil moisture levels on uptake of P_2O_5, in the above described irrigation experiment radiophosphorus was

applied at seeding at the rate of 80 pounds P_2O_5 per acre in factorial combination with 0 and 100 pounds of N and the three irrigation treatments. At four sampling dates the P_2O_5 derived from the fertilizer was determined as a percentage of the total P_2O_5 contained in the plants. Soil moisture was not a variable until after the first two samplings.

On May 30, at thinning, approximately 75 per cent of the P_2O_5 in the plants was derived from fertilizer; effects of N were not significant. Significant effects of N were observed on June 18 and August 1; beets from the 0 and 100 pounds N plots, respectively, had derived from the fertilizer 78.5 and 68.3 percent, and 49.9 and 38.7 percent, of their P_2O_5 content from the fertilizer at the two dates. By September 19, N effects were not significant. Irrigation treatment effects were significant on September 19, at final sampling. The beets of the M_1, M_2 and M_3 plots, respectively, had obtained 32.6, 37.4 and 35.8 percent of their P_2O_5 from the fertilizer. The least significant difference was 3.8 percent.

Without fertilizer the average yield of beets in this experiment was 12.5 tons of roots per acre. The yield was increased to 17.7 tons by 80 pounds of P_2O_5. The 17.7 tons of roots and accompanying tops contained 27.7 pounds of P_2O_5. Of this amount 17.4 pounds were derived from that P_2O_5 initially in the soil. From the 80 pounds applied as fertilizer only 10.3 pounds, or 12.9 percent, were absorbed by the plants.

Effect of Time and Method of Fertilizer Applications

The effects of differences in time and method of application of factorial combinations of 0, 50, and 100 pounds of N and 0 and 100 pounds of P_2O_5 per acre were investigated on one farm in 1951. Times and methods were as follows: (1) all fertilizer broadcast on the surface and disked in (March 23) before planting beets, (2) all fertilizers banded beside the row at planting, (March 30), (3) all the P_2O_5 and half the N broadcast and disked in before planting, half the N banded July 9, (4) all the P_2O_5 and half the N banded beside the row at planting, half the N banded July 9, and (5) all fertilizers banded beside the rows after thinning (May 18). Beginning May 20, a total of 16 irrigations was given during the season.

Significant increases in yield of beets and sugar were produced by N. Effects of P_2O_5 and time and method of application were not significant. Average yields for 0, 50, and 100 pounds of N per acre, with both levels of P_2O_5, were, respectively, 16.3, 19.1 and 21.6 tons per acre. The least significant difference was 1.03 tons. Average yields for the five times and methods of application were (1) 18.8, (2) 19.9, (3) 19.1, (4) 18.3, and (5) 19.1 tons per acre. Apparently the soil was able to supply sufficient N for the needs of the plants until thinning time, seven weeks after planting. Owing to this, and the fact that phosphate was not required, differences in time and method of applicaion were without significant effect on this soil.

Laboratory Soil Tests and Fertilizer Responses

The general response to N and lack of response to P_2O_5 and K_2O in these experiments emphasizes the need for a laboratory test from the results of which the need for N may be predicted at the beginning of the cropping season.

Soil samples were taken from each replication, or block, of each experiment before application of any fertilizers. Sampling depths were 0-6,

6-12 and 12-24 inches in 1950 and 0-8, 8-16 and 16-24 inches in 1951. Each sample for the first two depths was composited from six random borings; three borings were composited for the 12-24 and 16-24 inch samples. Samples were analyzed for total N (Kjeldahl), nitrifiable-N (2) CO_2-soluble (5) and H_2O-soluble (4) PO_4, exchangeable K, organic matter, pH, exchange capacity and exchangeable Na.

Yield responses were not related to total N, organic matter, pH, exchange capacity, or exchangeable Na. Total N ranged from 0.04 to 0.2 percent, with most surface samples in the range 0.08 to 0.14 percent. The range in organic matter was 1.1 and 4.1 percent in the surface and 0.4 to 2.8 percent in the lower depths. Soil reactions were all within the favorable range from pH 6.8 to 8.2. Exchange capacities ranged from 16 to 48 m. e. per 100 g.; most samples had exchange capacities of around 25 m. e. per 100 g. Exchangeable Na ranged from 0.7 to 1.7 m. e. per 100 g. in the surface six inches of soil.

Table 4.—Yield of Beets from 0 and 100 Lbs. N and ppm Nitrifiable—N in Soil Before Treatment.

9 Farms, Sig.							6 Farms, N.S.						
	Yield T./A.		Nitrifiable N, ppm.					Yield T./A.		Nitrifiable N, ppm.			
	Lbs. N/A.		Depth					Lbs. N/A.		Depth			
Farm	0	100	0-6"	6-12"	12-24"	Mean	Farm	0	100	0-6"	6-12"	12-24"	Mean
1	17.2	21.9	39	30	13	24	7	21.5	23.5	43	38	22	31
2	22.1	26.1	51	34	23	33	8	25.1	31.0	68	51	33	46
3	7.9	12.9	33	22	7	17	9	21.5	19.9	40	26	22	27
4	22.2	27.0	23	20	13	17	10	25.1	22.8	94	98	32	64
5	16.1	19.3	45	26	10	23							
6	15.0	17.4	48	20	7	20							
			0-8"	8-16"	16-24"					0-8"	8-16"	16-24"	
11	16.3	21.6	48	20	9	26	14	26.6	30.8	51	37	22	36
12	31.8	36.8	41	40	34	38	15	29.6	28.5	60	17	8	28
13	24.9	28.6	44	26	19	30							
Mean	19.3	23.5	41	28[1]	16[1]	25		24.9	26.1	59	48[1]	25[1]	39

[1] 1951 values corrected to 0-6, 6-12, 12-24-inch depths.

In Table 4 are presented the data for nitrifiable-N found in the soils after three weeks' incubation at 35° C. Soils are grouped on the basis of yield response to N. Each datum is the average of four samples. In general, there was less nitrifiable-N in each depth of the nine farms giving significant yield response to N than in the same depths of the six farms on which there was no response to N fertilizers. The mean values for the 0-6, 6-12 and 12-24 inch depths of the two groups of farms were, respectively, 41, 28 and 16 ppm. and 59, 48, and 25 ppm. The responsive soils averaged 25 ppm. N for the 24 inches, while the non-responsive group averaged 39 ppm. The most consistent differences between the two groups of soils appear to be in the 12-24 and 16-24 inch depths. Two farms in the responsive group gave N value similar to those of the non-responsive group. The organic matter content of the soil of Farm 2 was 4.1, 3.5 and 2.8 percent for the three depths, which values were twice as high as those for the other soils. Farm 12 produced an exceptionally high yield of beets, 31.8 tons per acre, without N, and five tons additional with 100 pounds of N. The nitri-

fiable-N in the soil from this farm was fairly high. It would appear that good cultural practices or other factors may account for the response to additional N on this soil.

Soils were tested for both water-soluble (4) and CO_2-soluble PO_4 (5). A beet yield response to P_2O_5 obtained on only one farm. By both methods of testing the soil of that farm was distinctly lower in PO_4 than the soil of other farms, the values being 0.2-0.3 ppm. water-soluble, and 1-3 ppm. CO_2-soluble PO_4. None of the 14 soils unresponsive to P_2O_5-tested below 0.5 ppm. water-soluble, or 5 ppm. CO_2-soluble PO_4 in the surface six, or eight, inch depth. Two of the non-responsive soils tested 0.2-0.3 ppm. water-soluble PO_4 in the 6-12-inch depth and 2-3 ppm. CO_2-soluble PO_4 in the 12-24-inch depth. On 12 farms the values for CO_2-soluble PO_4 fell between five and 20 ppm. at the three depths; values for water-soluble PO_4 were, for the most part, in the range 0.5 to 3 ppm. These data indicate that responses of sugar beets to P_2O_5 would probably not occur on soils similar to these if more than 0.5 ppm. water-soluble or 5 ppm. CO_2-soluble PO_4 is present.

Analyses for exchangeable K showed a range from 1,030 to 2,800 pounds K_2O per acre in the plow layer and additional large amounts in the lower depths. The total exchangeable K_2O ranged from 2,360 to 8,900 pounds in the 24-inch depth of soil. No beneficial response to K_2O was observed on any of these soils. There were indications of decreased yields from additional K_2O on some of them.

Summary

During the 1950 and 1951 seasons 15 fertilizer experiments with sugar beets were conducted on widely distributed farms in Malheur County, Oregon. Fertilizer variables were N at 0, 50, 100, 150 and 200 pounds; P_2O_5 at 0, 40 and 80 pounds, and K_2O at 0, 80 and 160 pounds per acre, in factorial combinations. Fertilizer treatments were replicated four times in randomized blocks. Further variables were plant density (three tests), irrigation treatment (one test) and time and method of fertilizer application (one test).

Substantial increases in yield of beets and sugar per acre were produced by N on nine farms, although high applications of N tended to reduce percent sugar. A yield increase from P_2O_5 was obtained on only one farm; 13.3 and 19.6 tons per acre, respectively, were produced with 0 and 80 pounds P_2O_5. The use of radioactive fertilizer revealed that on this P-deficient soil about 65 percent of the P in the plants was derived from the initial soil supply and only about 13 percent of the 80 pounds P_2O_5 applied in fertilizer was absorbed during the season. No beneficial response to K_2O was observed. Closer plant spacing increased yield of beets on one farm, yield of sugar on two farms. Irrigation treatment had significant effects. Differences in time and method of fertilizer applications were without effect.

Soil samples were taken to the 24-inch depth, in three increments, before application of fertilizers. The soils not responsive to N averaged about 50 percent higher in nitrifiable-N than the responsive soils. The one soil responsive to P_2O_5 tested markedly lower than the other soils in both water- and CO_2-soluble PO_4. Large amounts of exchangeable K_2O were found in all soils.

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The Response of Sugar Beets to Fertilizers in Western South Dakota[1]

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The yields of sugar beets on the Belle Fourche irrigation project in western South Dakota usually average about 10 tons per acre. In order to increase these yields, the Utah-Idaho Sugar Company has conducted numerous field trials with fertilizers (1) (2)[3].

Data from these have shown that applications of nitrogen and phosphate frequently increase the yields. In addition to the field trials, the Utah-Idaho Sugar Company conducted a soil sampling survey of fields where beets were grown to determine the levels of available phosphorus (3). The results of this study show that 68 percent of the samples contained only zero to five ppm. of CO_2-soluble PO_4. This level is considered very low. Other data obtained on the Newell Irrigation and Dryland Field Station tend to support these observations (4).

In order to study more intensively the nutrient needs of sugar beets in the area, six experiments on farmers' fields were conducted in 1950 and 1951. It is the purpose here to present the results from these experiments and to attempt to explain the observed responses in light of supporting data from soil and plant analyses.

The Belle Fourche irrigation project consists of approximately 50,000 acres. Part of the soils are sandy. These lie along the Belle Fourche river and range in textures from sandy loams to loams. Included in this category are the soils of the Vale and Nisland areas. Row crops such as corn, sugar beets and beans are more frequently grown on the sandy soils than on the finer-textured soils occurring elsewhere on the project. Clay soils occur over much of the remainder of the project. These include the Orman clay on the Arpan flats laid down in an old lake bed, and the Pierre clay in the vicinity of Newell which developed from weathering of Pierre shale. The clay soils are difficult to till and irrigate and stands of beets usually are poor. The clay soils are better adapted for small grains and alfalfa although considerable acreages of beets are grown on them. Beet yields on the clay soils over the past eleven years averaged only eight and one-tenth tons per acre as compared with 10.4 tons on the sandy soils.

Experimental Procedure

The six fertilizer experiments were conducted on six separate commercial sugar beet fields. The preparation of the land, planting, cultivation and irrigation were done by the farmer. The placement of the fertilizer, supervision of thinning and harvesting were done by Station personnel.

Four of the experiments were conducted in 1950 and two in 1951. Locations of the experiments, soil types, past management information and

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[2] Soil Scientist, Division of Soil Management and Irrigation.

[3] Figures in parentheses refer to literature cited.

supplementary soil and plant data are given in Table 1. Nitrogen and phosphate rates and combinations used are shown in Table 2 for the 1950 experiments and in Table 3 for the 1951. Double superphosphate was used as the source of phosphate and ammonium nitrate as the source of nitrogen. The phosphate was banded two inches deep and two inches to the side of the row with a belt-fertilizer machine soon after planting. The nitrogen was side-dressed at thinning.

The fertilizer treatments were replicated five times in a randomized block design. Each plot was four or six beet rows wide and 50 feet long. Two of the center rows were used for yield determinations while 15 beets from the harvest area were selected for sugar determination. Gypsum blocks were placed at each location for the purpose of obtaining moisture records and as a guide in advising the farmer when to irrigate. Soil samples were taken at zero-eight-inch depths from each location and the CO_2-soluble phosphorus, nitrifiable-nitrogen, percent organic matter, percent free lime, base exchange capacity, pH, electrical conductivity and percent water at

Table 1.—Location, Soil Type, Management History, and Soil and Petiole Analyses for Each of the Six Sugar Beet Experiments.

Location	1950 Experiments				1951 Experiments	
	Newell	Arpan	Vale	Nisland	Vale	Nisland
Soil type	Pierre clay	Orman clay	Vale f.sa.l.	sa.l.	Vale sa.l.	gravelly l.
Past management						
1950	———	———	———	———	Beans	Wheat
1949	Barley	Beets (M)	Corn	Beets (M, F)	Beans	Barley
1948	Barley	Beets (F)	Alfalfa	Beets	Beets (F)	Beets(M)
1947	Alfalfa	Barley	Alfalfa	Alfalfa	Beets	———
Beets per 100 ft.	72	81	81	74	95	91
Avail. PO_4, ppm.	1	23	6	14	2	13
Nitrifiable N, ppm.	84	50	82.5	54.8	----	
Organic matter, %	1.9	1.8	1.5	1.7		
Free lime, %	3.1	0.5	0.1	1.2		
Base exch. cap., m. e/100 gms	26.4	16.0	9.0	8.7		
Conductivity, millimhos	1.5	1.9	0.9	1.3	1.5	1.8
% water, ⅓ atmos.	44.4	32.8	16.0	20.6		
Petioles—Check plots						
Organic N, ppm.	6,900	3,050	5,250	4,400	3,970	3,440
Nitrate N, ppm.	15,000	1,650	4,500	3,500	910	620
Total soluble N, ppm.	21,900	4,700	9,750	7,900	4,880	4,060
Phosphorus, ppm.	1,000	2,520	560	870	380	2,200

M—Barnyard manure applied.
F—Commercial fertilizer usually about 250 pounds 16-20-0 per acre.

one-third atmosphere tension were determined either at the Newell Irrigation and Dryland Field Station laboratory or by Dr. W. E. Larson at Bozeman, Montana, using standard procedures. The sucrose content of the beets was determined by the Utah-Idaho Sugar Company. Petiole samples were collected in late August and the soluble nitrogen and phosphorus contents determined by Dr. J. L. Haddock at Logan, Utah, in 1950 and at Newell in 1951.

In 1951, in addition to the normal field topping procedure, the tops were cut flush with the crowns and green weights for tops, crowns and roots

were determined at harvest time. The percent dry matter was determined on samples of the beet raspings and of the tops.

Results and Discussion

The root yields for the experiments conducted in 1950 are given in Table 2 and for 1951 in Table 3. Fertilizer significantly increased the yield in four of the six locations although some increases were obtained at all locations. Yields of the unfertilized plots ranged from 7.1 to 19.2 tons per acre. Yield increases from fertilizers ranged from 1.9 to 8.0 tons per acre, and there appears to be a wide range in fertility needs from field to field.

The responses by locations are summarized as follows:

1. At Arpan, nitrogen increased the yields but phosphate had no beneficial effect. The yields increased with each increasing rate of nitrogen.
2. At Newell, phosphate increased the yields but nitrogen had no effect. Largest increases per pound of applied P_2O_5 were obtained from the 40-pound rate of P_2O_5, although yields increased slightly up through the 160-pound rate of P_2O_5.
3. At Nisland in 1950, a combination of nitrogen and phosphate appeared most effective—with 80 pounds of N and 80 pounds of P_2O_5 giving near maximum response.
4. At Nisland in 1951, nitrogen markedly increased the yields, while phosphate had little effect. The 40-pound rate of nitrogen gave by far the largest increase per pound of applied N.
5. At Vale in 1950, no significant increases were obtained from either nitrogen or phosphorus, singly or in combination.
6. At Vale in 1951, very slight but not significant increases apparently exist. Most of the increases may be ascribed to phosphate.

Table 2.—1950 Data Comparing Root Yields and Sugar Percentage from Various Nitrogen and Phosphate Applications at Four Locations.

Treatment Lbs. per acre		Newell		Arpan		Vale		Nisland	
N	P_2O_5	Roots T/A.	% Sugar	Roots T/A.	% Sugar	Roots T/A.	% Sugar	Roots T/A.	% Sugar
0	0	10.1	16.3	7.1	18.3	19.2	15.1	16.2	17.4
0	160	12.2	16.6	7.3	18.2	20.3	15.0	17.7	17.1
40	160	12.5	16.1	8.9	18.5	20.5	14.8	18.5	16.5
80	160	12.2	16.2	9.5	18.9	19.7	14.6	19.2	16.7
160	160	12.3	16.1	10.2	18.5	21.1	14.4	19.6	14.9
80	0	8.6	16.3	10.2	17.9	19.3	14.8	16.4	15.4
80	40	11.3	16.2	9.1	18.0	19.8	14.7	18.1	16.2
80	80	11.5	16.2	8.5	18.5	19.7	15.0	19.3	15.5
LSD	.05	1.9	N.S.	1.7	N.S.	N.S.	N.S.	2.1	1.2

Although the yields on most of the low-producing fields were improved through fertilizers, really high yield increases were obtained only at Nisland in 1951. Apparently factors other than a deficiency of nitrogen and phosphorus are responsible such as poor stands, disease injury and poor physical condition of the soil.

Table 3.—1951 Data Comparing Root Yield, Sugar Percentage and Top Yields from Various Nitrogen and Phosphate Applications at Two Locations.

Treatment Lbs. per acre N	P_2O_5	Vale Roots T/A.	Vale % Sugar	Vale Tops[1] T/A.	Vale Root/Top[2] Ratio	Nisland Roots T/A.	Nisland % Sugar	Nisland Tops T/A.	Nisland Root/Top Ratio
0	0	11.4	18.4	4.5	2.53	10.0	18.7	3.8	2.63
0	80	13.8	18.2	5.4	2.56	9.8	18.9	4.0	2.45
40	80	13.0	18.7	4.8	2.71	16.0	18.2	7.1	2.25
80	80	13.1	18.5	6.5	2.02	15.9	18.5	8.6	1.85
120	80	13.4	17.7	6.8	1.97	18.0	18.2	10.9	1.65
80	0	12.1	18.0	6.4	1.89	15.5	18.0	8.9	1.74
80	40	13.1	17.8	6.7	1.96	17.4	18.6	9.5	1.83
LSD	.05	N.S.	N.S.	1.8		2.1	N.S.	2.3	

[1] Green tops, does not include the crown. The average yield of the crowns was approximately 7 percent of the roots.
[2] Tons roots divided by tons tops.

Percent sugar

A linear regression was computed between root yields and percent sugars from the data for the four sandy soil locations. Preliminary regressions indicated that the data from the two clay soil locations behaved entirely differently from those of the sandy soils, and since only 16 pairs of values were available for the clays, regressions for the latter were not computed. The regression line for the 30 pairs of values for the sandy soils is shown in Figure 1.

For this set of data, the regression equation was $Y = 23.45 - .4008x$ and the regression coefficient was $r = -.83$, a highly significant value. For the sandy soils, each ton increase in beet yield was associated with an 0.4 percent decrease in the sugar content. Insufficient data existed for the preparation of a valid regression line on the clay soils; nevertheless, it is interesting to point out that, for a given yield, the percent sugars are lower on the clays than on the sands. This is apparent in Tables 2 and 3 by comparing certain of the yields and sugar percentages from Newell with the 1951 Nisland data, and from Arpan with the 1951 Vale data.

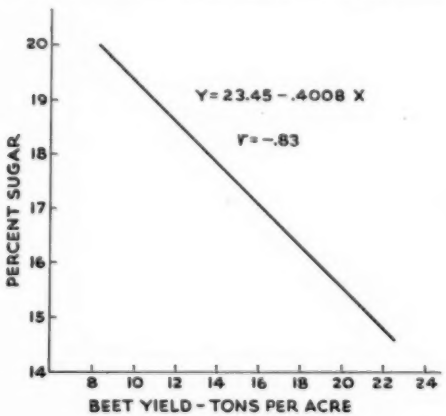

Figure 1. Average regression of percent sugar on beet yield in four field experiments located on sandy soils.

At most locations, applications of nitrogen tended to reduce the sugar percentage. This reduction was great enough to be significant only at Nisland in 1950. Here the 160-pound nitrogen rate decreased the sugar contents by two and two-tenths percent below that of the phosphated check. This resulted in an actual decrease of 230 pounds of sugar per acre even though the nitrogen increased the root yield by one and nine-tenths tons. In the same experiment, the 40- and 80-pound nitrogen rates resulted in an average depression in sugar content of five-tenths percent below that of the phosphated check.

At Arpan, on the other hand, nitrogen in the presence of 80 or 160 pounds of P_2O_5 apparently had no deleterious effect on the sugar content even though the beet yields were increased by as much as two and nine-tenths tons. It is interesting, however, that 80 pounds of nitrogen either alone or in the presence of 40 pounds of P_2O_5 appear to have decreased the sugar content.

Phosphate appears to have exerted but little depressive influence upon the sugar percentage. In fact, a combination of nitrogen and phosphate generally showed smaller depressive effect than where the same amount of nitrogen was used alone.

Production of Tops

The 1951 yields of green tops and the corresponding root/top ratios point out some interesting comparisons (Table 3).

At both locations, increasing the rate of nitrogen in the presence of phosphate decreased the root/top ratio, i. e., increased the proportion by weight of tops to roots. Increasing the rate of phosphate in the presence of nitrogen, on the other hand, slightly increased the root/top ratio, i.e., decreased the proportion of tops to roots. Nitrogen alone decreased the root/top ratio to a greater extent than the same rate of nitrogen in the presence of phosphate, thus indicating that nitrogen alone produced more tops in proportion to the roots than did a combination of nitrogen and phosphate.

Representative samples of root raspings and green tops were oven dried for the determination of the percent dry matter. The dry matter content of the roots did not vary more than one percent between treatments. However, in the case of the tops, there was as much as five percent less dry matter per unit of green material in the large green tops from the nitrogen plots as from small yellow-green tops collected from the no-nitrogen plots.

General Relationships

The foregoing data show that root yields, sugar percentages and growth of tops vary considerably between locations. Can reasons for these variations be accounted for?

At Arpan, on the Orman clay, large root response to nitrogen was obtained; however, nitrogen in the presence of high rates of phosphate had no depressing effect upon the sugar percentage. Table 1 shows that the soil samples collected from this location contained 23 ppm. of CO_2-soluble PO_4, the highest at any location, and 50 ppm. of nitrifiable nitrogen—the lowest reported. The analysis of the beet petioles taken from check plots

confirms the soil analysis, i.e., high in soluble phosphorus and low in the soluble nitrogen fractions. From the soil and petiole analysis, one would expect the large response to nitrogen and the lack of response to phosphate. Although manure and fertilizer were applied to the field during the three-year period preceding the experiment, no legume crops were grown during these years. Earlier history indicates that the field was poorly managed and received no manure or fertilizers. Apparently, however, the level of available soil nitrogen was so low that even 80 or 160 pounds of fertilizer nitrogen per acre when applied with 80 or 160 pounds of P_2O_5 were insufficient to cause depression in sugar content of the beets. Why some depression in sugar content resulted when 80 pounds of nitrogen were applied either alone or with 40 pounds of P_2O_5 is not explainable from the data available.

At Newell, on the Pierre clay, phosphate increased the yields but nitrogen had no effect. Table 1 shows that the soil contained only one ppm. of CO_2-soluble PO_4, while the petioles contained 1,000 ppm. of soluble phosphorus, much lower than at Arpan on a soil having somewhat similar texture. Nitrifiable nitrogen, however, was high (84 ppm.), and the soluble nitrogen fractions in the petioles were extremely high. This field had been in alfalfa from 1947 and for several years previously and phosphate or manure had not been applied. These observations indicate a low level of available phosphorus and a high level of available nitrogen in the soil which correlate well with the observed yield response. One would expect, however, that the sugar percentage of the beets would have been decreased to a greater extent from the application of nitrogen.

At Nisland on a sandy loam in 1950, a combination of nitrogen and phosphate fertilizer was most effective, while nitrogen greatly depressed the sugar content. The soil analysis shows that the soil contained a moderate supply of 14 ppm. of available PO_4; the nitrifiable nitrogen, however, was 54.8 ppm., considerable lower than on the clay soil at Newell but slightly higher than at Arpan. Petiole analyses showed a comparatively low level of both soluble phosphorus and soluble nitrogen. This field had been in alfalfa three years previously and had received manure and fertilizer in 1949. While these observations would lead one to expect a response to nitrogen and phosphate, it is by no means as clear-cut as the nitrogen at Arpan or the phosphate at Newell. However, the check yield at Nisland was 16.2 tons as compared to seven and one-tenth and 10.1 tons at Arpan and Newell, respectively.

At Vale in 1950, significant yield responses were not obtained; however, the yield of the check plots averaged 19.2 tons per acre. Phosphorus analysis of both the soil and the petioles indicate a low level of available phosphorus. Why phosphate response was not obtained is not known. Nitrogen analysis of the soil and petioles indicates that the nitrogen level was quite high.

At Vale in 1951, no significant yield responses were obtained, although there was a tendency for phosphate to increase the yields by about one ton per acre. Observations made early in the season also indicated a vegetative response to phosphate. The top yields were significantly increased from

80 pounds of nitrogen alone and from the 80- and 120-pound rates of nitrogen in combination with phosphate. The available PO_4 level in the soil was only two ppm. while the petiole phosphorus also was extremely low. The soluble nitrogen fractions in the petioles were low. The lack of legumes on the field in the past would tend to support the low levels of soluble nitrogen in the petioles. Why final yield responses were not obtained from nitrogen and phosphate cannot be explained.

At Nisland in 1951, a very large response to nitrogen of both roots and tops was obtained. Phosphate had no effect. The CO_2-soluble PO_4 content of the soil was 13 ppm. while the soluble phosphorus in the petioles was high. The soluble nitrogen fractions in the petioles were very low, equalled only at Arpan. No legumes were grown on the field for several years in the past. Thus, all indications point to a moderate to good supply of available phosphorus and a very low supply of available nitrogen in the soil, which explains satisfactorily the type of yield response obtained. Although nitrogen fertilizer did not significantly reduce the sugar content of the beets, the reduction nevertheless was considerable.

Summary

Results presented from six fertilizer experiments conducted on the Belle Fourche irrigation project in western South Dakota show that response to nitrogen and phosphate varies greatly from field to field.

These responses correlated well with soil and petiole analyses in four instances but not in two.

Nitrogen fertilizer at some locations lowered the sugar content of the beets. This was particularly serious at only one location. Increase in yield was closely associated with a reduction in sugar content.

Root/top ratios indicate that nitrogen fertilizer increased the proportion by weight of tops to roots while phosphate slightly decreased the proportion of tops to roots. Nitrogen alone increased proportion tops to roots to a greater extent than did a combination of nitrogen and phosphate.

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A Survey of Soil Organic Matter Levels and Their Relationship to Nitrogen Needs

BION TOLMAN, ROBERT S. GADDIE AND RONALD C. JOHNSON[1]

A report of the general survey of the levels of available phosphate in the soils in Utah, Idaho, Washington, Montana and South Dakota was made in the 1950 Proceedings of the American Society of Sugar Beet Technologists. A report is now made of a similar survey of the levels of organic matter.

It is recognized that the organic matter levels in the native soils of these areas will vary according to soil type and temperature and vary further on cultivated soils depending upon cultivation, crop history, amount of organic matter which has been returned to the soil and general soil management. It was the aim of this survey to help find the average content of organic matter in the soils of each area and to establish a correlation between organic matter levels and nitrogen needs.

Table 1.—Amount of Organic Matter in the Soil from the Back-Titration Figures of Ferrous Ammonium Sulfate.

Back Titration of Ferrous Ammonium Sulfate	Percentage Organic Matter	Tons Organic Matter per Acre	Approximate Lbs. N per Acre
18.1	0.5	5	500
16.3	1.0	10	1,000
14.5	1.5	15	1,500
12.6	2.0	20	2,000
10.7	2.5	25	2,500
8.9	3.0	30	3,000
7.0	3.5	35	3,500
5.2	4.0	40	4,000
3.3	4.5	45	4,500
1.5	5.0	50	5,000

During the last six years more than 450 field trials with commercial fertilizer have been conducted by the Utah Idaho Sugar Company in cooperation with farmers throughout the area in which it operates. These trials were designed to determine the deficiency of both nitrogen and phosphorus.

The correlation of organic matter levels with nitrogen needs was made by determining the organic matter level on the unfertilized check plots of each field trial and correlating the organic matter level found with yield increases obtained on plots receiving nitrogen applications.

After extensive comparisons it was decided that there was a correlation between organic matter level and nitrogen needs, that soil tests could be used to supplement data obtained from field tests and that organic content levels could be helpful in estimating nitrogen needs when allowances were made for cropping and fertilizer history; and with this information an extensive soil sampling and soil analysis program was undertaken.

[1] General Agricultural Superintendent, General Chemist and Assistant Research Director, respectively, Utah-Idaho Sugar Company.

Soil Testing Procedures

Obtaining the Soil Sample

All soil samples were taken by members of the Sugar Company field staff. The sample from each field test was obtained by using a small soil sampling tube which could be pushed into the top six or eight inches of soil. At least 12 small samples were obtained over the field area, and the soil was mixed thoroughly in a bucket. A composite sample of 1.5 pounds of soil from each field sampled was sent to the local factory chemist to be air-dried, sieved and reduced to 100 grams by use of the Jones sampler. At regular intervals as sufficient samples were accumulated they were sent to the general laboratory for analysis.

Table 2.—Results of Soil Analyses for Organic Matter, Showing the Percentage of the Samples Falling into Each of the Organic Matter Groups. 1950.

District	0.5 Percent	1.0 Percent	1.5 Percent	2.0 Percent	2.5 Percent	3.0 to 4.0 Percent	4.0 and over Percent	No. of Samples
Gunnison	5	24	30	31	9	1	0	63
West Jordan	10	19	28	26	7	9	1	167
Garland	1	10	27	30	21	8	3	219
Idaho	3	31	29	21	4	1	1	403
Washington	39	26	22	4	9	0	0	23
Montana	3	14	35	22	12	8	6	82
South Dakota	1	9	29	35	16	10	0	214
Nebraska	0	0	5	18	11	55	11	38
Weighted Average	4	19	31	26	11	7	2	1,209

Methods of Analysis

The method used for determining organic matter percentage in soils is essentially that of Walkley and Black. Some modifications have been made and the detailed procedure is outlined below:

Reagents:—Primary standard $K_2Cr_2O_7$, 4N—Grind and dry at 120° C. to 140° C. reagent grade $K_2Cr_2O_7$. On the analytical balance weigh out 196.1430 g. of $K_2Cr_2O_7$. Dissolve in water and dilute to one liter at 20° C.

H_2SO_4 36 N—to each liter concentrated H_2SO_4 add 1.25 g. Ag_2SO_4 H_3PO_4, 85 percent.

Diphenylamine—dissolve three gm. in 100 ml. $36NH_2SO_4$.

Ferrous Ammonium sulfate, 0.2 N—70 gm. of salt plus 20 m. 36 N H_2SO_4 made up to one liter. Adjust to 0.2 N by titrating against the four N $K_2Cr_2O_7$ using disphenylamine as indicator as described under "procedure." This solution should be checked once each week as it is only fairly stable.

Procedure:—Weigh out into a 150-ml. beaker, 0.500 $\pm$ 0.005 gm. of the dry powdered soil. Add (with a pipette) exactly one ml. 4N $K_2Cr_2O_7$ and 10 ml. 36 N H_2SO_4 containing the Ag_2SO_4. Heat on a hot plate until white fumes just appear (175° C.) Cool, add approximately 100 ml. distilled water (caution), five ml. 85 percent H_3PO_4 and two drops of disphenylamine solution. Titrate with 0.2 N ferrous ammonium sulfate until

the blue color disappears and the green color appears. When using this amount of soil and one m. of $K_2Cr_2O_7$, the amount of organic matter in the soil from the back-titration figures of ferrous ammonium sulfate is shown in Table 1.

The factor for organic matter per ml. of $K_2Cr_2O_7$ is 0.027 for the 0.500 gm. sample taken. If soil analyzed is more than five percent organic, two ml. of the $K_2Cr_2O_7$ must be used. For very high organic content use 0.100 gm. soil.

The color is not always purple or blue on adding the indicator at the beginning of the titration, but this color always appears, just before the end point when the color flashes to green. This occurs with little or no warning.

Silver sulphate is used to prevent chlorine interference in saline soils. Sufficient silver ion is present to precipitate the chlorides as AgCl, and so prevent the oxidation by the chromic acid.

Large amounts of $CaSO_4$ from our calcareous soils along with AgCl tend to alter the shades of the color produced. The color change at the end point, however, is still quite sharp and easily recognized.

Table 3.—Relationship of Organic Matter Levels to Yield Response in Field Tests.

	Organic Matter Levels					
	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%
Percent of tests responding to nitrogen applied alone	90	94	75	75	85	80
Percent of tests responding to phosphate applied alone	40	88	75	69	43	60
Percent of tests which gave greatest response to a mixture of nitrogen and phosphate	70	88	88	94	86	80
Percent of tests which gave greatest response to nitrogen applied alone	30	6	8	6	0	0
Percent of tests which gave greatest response to phosphate applied alone	0	6	4	0	14	20

Analytical Results

A summary of the organic matter content levels in soils from various areas are shown in Table 2. It is evident from the data that the organic matter levels varied greatly both within and between districts.

It is recognized that organic matter levels should vary between areas and soil types. However, each area furnished examples of what proper organic levels should be in soils where good management practices were being followed, and when due allowance for the effect of the previous crop and previous fertilizer history was made, the organic matter level proved helpful in estimating nitrogen needs.

Relationship of Soil Analysis to Field Tests

In all the field trials nitrogen and phosphate fertilizers were tested both alone and in combination. Thus in any one test it was possible to compare yields from plots receiving either phosphate or nitrogen alone with

yields from unfertilized plots, and also to compare the yield from plots receiving nitrogen and phosphorus with the yield from plots receiving either phosphate or nitrogen alone. Soil samples were obtained on all plots not receiving phosphate, and this made it possible to correlate chemical soil tests with actual yield responses in the field. The relationship found between the chemical tests and nitrogen responses from field tests is shown in Tables 3 and 4.

Table 4 shows that in Washington, Utah and Idaho there was a tendency for a smaller yield increase and percent yield increase from the application of 400 pounds of ammonium nitrate as the organic matter level increased. Montana and South Dakota did not follow this tendency. These two areas, probably because of their complicated soil problems, seldom conform to any general fertilizer practice.

Table 3 shows that most of the tests gave a response to phosphate and nearly all of the tests gave a response to nitrogen, irregardless of the organic matter level. However, as shown in Table 4, the magnitude of the increase decreased as the organic matter content increased. Table 3 also shows that a larger percentage of the tests gave the greatest response to nitrogen alone when the organic matter level was low and that a larger percentage of the

Table 4.—Relationship of Organic Matter Levels to Yield Increases from Nitrogen Application in Different Growing Areas.

Areas and Treatment	Organic Matter Levels					
	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%
Washington						
Yield of Checks	26.25	29.23	29.99	.....	34.76	.....
Increase from 400 pounds Ammonium Nitrate	6.19	3.67	4.95	.....	1.24	.....
Percent Increase	24	13	16	.....	4	.....
Idaho and Utah						
Yield of Checks	12.83	15.99	15.99	17.11	19.60	17.92
Increase from 400 pounds Ammonium Nitrate	2.98	1.85	1.72	1.24	1.86	1.72
Percent Increase	23	12	11	7	9	9
Montana and South Dakota						
Yields of Checks	.....	.....	15.15	11.04	13.22	14.15
Increase from 400 pounds Ammonium Nitrate	.....	.....	.69	1.50	1.53	0.45
Percent Increase	.....	.....	5	14	12	3

tests gave the greatest response to phosphate alone when the organic matter level was high, but that in a great majority of the tests the greatest response was obtained from a mixture of phosphate and nitrogen regardless of the organic matter level.

Table 5 shows the percent of tests in each organic matter level which gave the most profitable yield from the three amounts of nitrogen. In Utah, Idaho, South Dakota and Montana, the checks gave the most profitable yield only on fields with a high organic matter content while the highest rate of nitrogen (400 pounds of ammonium nitrate) gave the most profitable response on a large percentage of all the tests and on practically all of the

tests where the organic matter level was low. In Washington, where more nitrogen is needed because of a longer growing season and higher yields, the highest rate of nitrogen gave the most profitable yield in all of the tests regardless of the organic matter content of the soil. However, the fields with a low organic matter content gave larger increases than did the fields with a high organic matter level.

Table 5.—Relationship of Organic Matter Levels to Rate of Most Profitable Nitrogen Application.

Area and Treatments	Organic Matter Levels in Percent					
	0.5	1.0	1.5	2.0	2.5	3.0
Idaho, Utah, Montana, South Dakota and Nebraska						
Percent of tests which gave the most profitable yield from no nitrogen	0	0	0	0	0	40
Percent of tests which gave the most profitable yield from an application of 200 pounds A.N	0	22	24	44	50	20
Percent of tests which gave the most profitable yield from an application of 400 pounds A.N.	100	78	76	56	50	40
Washington						
Percent of tests which gave the most profitable yield from no nitrogen	0	0	0	0	0	0
Percent of tests which gave the most profitable yield from an application of 200 pounds A.N.	0	0	0	0	0	0
Percent of tests which gave the most profitable yield from application of 400 pounds A.N.	100	100	100	100	100	100

It is evident from these data that there are many cases where chemical tests did not tell the complete story. Some factors responsible for this situation are previous crop, kind of crop residues from the previous crop and previous fertilizer history. It is felt, however, that the results of the soil tests are very helpful when used by someone who has a knowledge of past cropping history, past fertilizer history, and who has available considerable information from field trials in the general area.

Effect of Nitrogen Supply on the Sucrose Percentage of Sugar Beets

KENNETH WILFORD HILL[1]

The primary objective in sugar beet culture is the production of a maximum quantity of sugar per acre. This necessitates abundant yields of roots with high sucrose content. A good supply of soil nitrogen is essential to high yields but excessive nitrogen may lower the percentage of sucrose. Thus, in order to give guidance to producers in the fertilization of commercial fields the agronomist must understand the relationship between nitrogen fertilization and the metabolism of the sugar beets, particularly in respect to sucrose formation.

In a rotation experiment in the sugar beet growing district of Southern Alberta, Canada, the sucrose content of sugar beets grown in a legume rotation has been consistently lower than that of sugar beets in a comparable non-legume rotation although the yields have been about equal. In the same area fall application of manure to sugar beet land has not depressed the sucrose content of the subsequent crop of beets nor have spring applications of nitrogenous chemical fertilizer.

This investigation was initiated to provide information on the relationship of the nitrogen in the soil to the sucrose content of beets grown thereon. The experiments were so planned as to provide a physiological explanation of the reduction in sucrose percentage due to the inclusion of alfalfa in a sugar beet rotation. A microbiological assay for glutamic acid was conducted on sugar beets grown under different nitrogen levels in the greenhouse since this amino acid has been shown to be useful as an index of nitrogen metabolism in the beet.

Several investigators (1) (2) (3) (5)[2] have reported results of studies on sucrose content of sugar beets as related to nitrogen content. However, no references were found to work wherein sugar beets showing a significant difference in sucrose percentage due to variation in nitrogen fertilization were analyzed for all fodder constituents (dry matter, protein, ash, fat, fibre, nitrogen free extract). Such analyses were made in this study on sugar beets from a legume and a comparable non-legume rotation and also on beets fertilized August 2, 1950, with 300 pounds of ammonium nitrate per acre as compared to unfertilized beets.

Experimental Procedure

These investigations were conducted under irrigation at the Dominion Experimental Station, Lethbridge, Alberta, Canada. The climate of the area may be compared roughly with that of northeastern Colorado and has a mean annual temperature of 41° F., annual precipitation of 16 inches, and an average growing season of 141 days. The soil is a chestnut loam of high natural fertility and excellent structure.

The two rotations studied were: 1—an eight-year cycle of beets, beets, wheat, wheat and alfalfa, alfalfa, alfalfa, alfalfa, wheat; and 2—a four-year sequence of beets, beets, wheat, barley. These two rotations were laid down in duplicate in 1929. The plots of the two rotations were contiguous and the individual plot size was 19.8 feet x 93.2 feet. Each plot was divided

[1] Agronomist, Dominion Experiment Station, Lethbridge, Alberta, Canada.
[2] Numbers in parentheses refer to literature cited.

into quarters by bisecting in two directions perpendicular to the borders and applications of manure[3] and phosphate fertilizer[4], singly and in combination, were assigned to three of the quarters. The fourth quarter was preserved as a check. These fertility treatments have been perpetuated on the original locations in each plot.

In addition to the usual yields and sucrose percentages of the beets produced, data have been obtained on the concentration of available nitrates in the soil of the various plots during the growing season of 1949. Petioles of the sugar beet plants were analyzed for nitrate nitrogen and total nitrogen in 1949 and 1950 respectively. In all cases duplicate determinations were made on duplicate plots.

The roots from the legume and non-legume rotations were analyzed for all fodder constituents as well as for sucrose. Similar determinations were made on roots from the manured and/or fertilized quarters of all plots in the two rotations to which had been applied the supplementary 300 pounds per acre of ammonium nitrate August 2, 1950. Correlation coefficients were calculated between sucrose percentage and the other plant constituents.

A supplementary test on nitrogen nutrition of beet roots and its effect on sucrose content was conducted in the greenhouse during the winter of 1950-51. In order to provide identical material for each of four nitrogen levels, 20 large roots from a commercial field were lifted on October 15, trimmed of all green material and quartered. Previous success in sectioning beet roots to provide additional units in a breeding program prompted this procedure. One quarter of each beet was assigned to each of four nitrogen series; thus the experiment constituted 20 replications (provided by the 20 original roots) of four treatments (the nitrogen levels). Each root section was planted in sterile sand contained in a one-gallon stone crock.

A balanced nutrient solution described by Weidemann and Cook, 1947, was used as a basic solution. The amount of nitrogen in this solution was designated as "normal" and this "normal" concentration was doubled, halved and omitted entirely to provide three additional nitrogen levels. The pots in all series received exactly the same amount of nutrient during the experimental period with the exception of the variation in nitrogen. The root sections in the "normal" nitrogen series each received 250 milligrams of nitrogen and those in the other series received 500, 125 and 0 milligrams respectively. After 14 weeks of growth the root sections were harvested and analyzed for sucrose, total nitrogen, dry matter, ash, fat and fibre. In addition a microbiological assay for glutamic acid was conducted on each root section. This assay procedure included extraction of the glutamic acid from the root with 99 percent isopropanol followed by addition of the extract to tubes containing a suitable basal medium inoculated with *Lactobacillus Arabinosus* 17-5. After incubation, the growth of the organisms were measured by titration of the acid produced. All determinations were made in triplicate.

[3] Thirty tons of manure per acre were applied in the fall previous to the first beet year to the appropriate plots in legume rotation and 20 tons to those in the non-legume rotation.
[4] One hundred pounds of triplesuperphosphate were applied in both rotations at the time of seeding the beets.

Root Yields

The 10-year averages (1941-50) for yields and sucrose percentages are reported since the length of the record smooths out annual variations and provides a better sampling of the different growing seasons than would a two-year average covering the experimental years, 1949 and 1950. Under similar fertilizer treatments the yields were nearly equal in the two rotations. Acre yields on plots treated with manure and phosphate fertilizer or manure only were about 20 tons, whereas plots which received only phosphate fertilizer produced approximately 13 tons. The check plots yielded seven and three tons per acre respectively on the non-legume and legume rotations.

Sucrose Percentages

The sucrose percentages of beets grown under the three fertilizer treatments (manure and phosphate fertilizer, singly and in combination) were very similar within each rotation. Thus no deleterious effect on sucrose percentage could be ascribed to the manure application. However, the 10-year mean sucrose content of beets on all plots, excepting the checks, in the legume rotation was 16.2 percent as compared to a mean of 17.4 percent in the non-legume rotation. The difference was statistically significant at the one percent point.

Nitrogen Content of Soils and Petioles

Available soil nitrates were higher in the plots of the legume rotation than in those of the non-legume and a similar relationship occurred in the manured plots compared with the unmanured within either rotation. The superiority of the plots in the legume rotation in this respect was particularly marked in the latter part of the growing season.

The content of nitrate nitrogen and total nitrogen of sugar beet petioles from the legume rotation was generally higher than the comparable values from petioles grown in the rotation which did not include alfalfa.

Analyses of Roots

The analyses for the various fodder constituents supplied information on the relative composition of beets of equal size which showed significant differences in sucrose percentage. The roots from the two rotations provided ideal analytical material for this study since their yields and field populations were about equal and the beets from the legume rotation were consistently inferior in sucrose percentage. Where 300 pounds of ammonium nitrate were added to a section of some of the plots in both rotations the yield was not affected but the sucrose percentage was reduced significantly. The analyses of these roots contrasted to analyses of comparable roots which did not receive any additional fertilizer indicated the same trends of differences as noted in comparison of the legume and non-legume rotations. These data are summarized in Table 1.

In a supplementary test 300 pounds of ammonium nitrate were added to sugar beets June 28. An increase of 25 percent in yield over unfertilized beets was recorded but the sucrose percentage was not affected. These results do not agree with those set forth in Table 1 and it is proposed that the

difference is due to the time of application of the fertilizer. Nitrogen fertilizer added June 28 brought about increased leaf growth and yield, whereas the same amount of fertilizer applied August 2 was too late to affect the yield, but apparently some of the nitrogen was taken up by the roots and its effect was expressed in a lower sucrose percentage.

Table 1.—Chemical Constituents of Sugar Beet Roots Grown in a Legume and a Non-legume Rotation and Also With and Without a Late Application of Ammonium Nitrate at Lethbridge, Alberta. 1950.

Treatment	Plant constituents in percent of green weight						
	Water	Sucrose	Total N.	Ash	Fat	Fibre	N-free extract[1]
Legume vs. non-legume rotation							
Legume	78.93[2]	16.12	.158	.660	.097	1.13	2.07
Non-legume	77.54	17.36	.137	.624	.082	1.24	2.30
Min. sig. difference	0.95	0.58	.016	.078	.....	.....	.....
Fertilized on August 2 vs. no fertilizer							
300 lb. NH_4NO_3 per acre	79.38	15.64	.167	.717	.080	1.233	1.91
No fertilizer	78.10	16.42	.147	.693	.092	1.188	2.59
Min. sig. difference	0.67	0.60	.016	.020	.....	.....	.....

[1] The nitrogen free extracts were derived by subtraction after having converted the total nitrogen to protein by the factor 6.25.
[2] Each statistic is the mean of at least 50 individual determinations.

It has been mentioned previously that an application of manure did not decrease the percentage of sucrose. Since it was possible to apply nitrogen in the form of chemical fertilizer early in the season and not affect the sucrose content of beets (thus paralleling the experience with manure), and furthermore since the same amount of chemical fertilizer applied late in the season reduced the sucrose content (thus paralleling the experience with nitrogen supplied by the legume), circumstantial evidence would indicate that the legume provides an excess of nitrogen late in the growing season.

Relationships Between Various Plant Constituents

Sucrose percentage showed a highly significant positive correlation with percentage of dry matter. This is understandable since sucrose makes up a major portion of the dry matter. No significant correlations were apparent between sucrose and ash, fat or fibre.

A highly significant, negative correlation was evident between the percentages of sucrose and total nitrogen. In addition, a partial correlation coefficient was calculated between sucrose percentage and total nitrogen percentage holding dry matter percentage constant. This r-value amounted to —0.505, which proved to be highly significant. This significant correlation between sucrose and nitrogen percentages independent of the moisture content of the roots is an important relationship.

It is interpreted to mean that the deleterious influence of nitrogen on sucrose percentage does not occur merely as a result of a "high-nitrogen" plant being more succulent, thus containing less sucrose and other dry matter. It seems more probable that a plant which is high in nitrogen may

be relatively low in sucrose content because more than a usual amount of the stored carbohydrates in the plant was used to provide energy for the reduction of the excessive nitrates which were taken up.

Greenhouse Experiment

The sections of the quartered roots survived well and produced new leaf growth although some individuals were damaged by disease and others by insects. The mean sucrose percentages (from 14 replications) of the roots in the four nitrogen series were as follows: 1. no nitrogen—10.94; 2. half-normal nitrogen—11.46; 3. normal nitrogen 10.81; and 4. twice-normal nitrogen—8.86; the mean dry matter percentage of the same four series were 15.41, 15.11, 14.37, and 13.02 respectively.

In sucrose percentage the twice-normal series was significantly lower than all others, thus these data leave little doubt as to the deleterious effect of the high nitrogen level on the sucrose content of these roots. There were only very small differences among the percentages of total nitrogen in the root sections of the four series. The values for total nitrogen in all series were considerably lower than the comparable values in the field roots discussed previously. Statistical analyses of the analytical data failed to show any significant differences among the four nitrogen series in respect to ash, fat or fibre.

The microbiological assay for glutamic acid proceeded very successfully in the laboratory. A standard growth curve for *L. Arabinosus* 17-5 was prepared by adding 0.015 milligram increments of standard L-glutamic acid to inoculated tubes containing a basal medium which included all the necessary nutrients (except glutamic acid) for the growth of the organism. The amount of growth in each tube was determined by titration of the acid produced. In assaying the root sections the amount of acid produced by organisms growing on the extract from the root section was referred to the standard curve and from this the glutamic acid concentration was read.

The concentration of glutamic acid in the root sections was generally less than 100 milligrams per 1,000 grams of root weight. This is somewhat lower than usual. Apparently the conditions of this experiment were not conducive to glutamic acid elaboration.

Although this microbiological assay added limited information concerning the nitrogen nutrition of sugar beets, it did advance knowledge of the experimental technique and this can now be extended with confidence to field material in southern Alberta.

Summary

1. **A legume rotation** has consistently produced beets of equal yield but lower sucrose percentage than a comparable non-legume rotation, and this investigation has sought to learn the reasons for this. Analyses have been made to determine the difference in chemical composition of sugar beets of the same weight which display significant differences in sucrose percentage.

2. **Soil analyses** have shown the legume rotation to be higher than the non-legume in soil nitrates particularly in the latter part of the growing season.

3. **Accordingly the beets** of the legume rotation have both a higher nitrate and a higher total nitrogen content as indicated by petiole tests.

4. **Three hundred pounds** of ammonium nitrate applied to beets on August 2 reduced the average sucrose percentage from 16.42 to 15.64, but the same amount of fertilizer applied on June 28 did not affect the sucrose content. The yields were increased in the latter case but not in the former.

5. **Beets from the legume rotation** were higher in nitrogen, water and ash but of equal size to beets from the non-legume rotation. A similar relationship occurred between the beets which received 300 pounds of ammonium nitrate August 2, and those which were unfertilized. This indicates that the time of the season at which the nitrogen is available has a very important bearing on the sucrose percentage.

6. **There are complex relationships** among nitrogen supply, vegetative growth, photosynthetic capacity and sucrose percentage. If supplementary nitrogen is applied early in the season it may stimulate vegetative growth and leaf area, thus increasing the capacity to manufacture carbohydrates and even though more sugar is used for energy to reduce the excess nitrates the net percentage of sucrose may not be lowered.

7. **A significant partial correlation** coefficient of $r = -0.505$ between sucrose percentage and nitrogen content with dry matter percentage held constant indicates that there is an inverse relationship between sucrose and nitrogen content independent of moisture relationships.

8. **In a supplementary test** in the greenhouse beet roots were quartered to provide identical genetic material and the respective quarters, which were grown in sterile sand for 14 weeks under four series, ascending in amount of nitrogen applied, displayed mean sucrose percentages of 15.41, 15.11, 14.37 and 13.02.

9. **A microbiological assay** for glutamic acid was conducted on the roots grown in the greenhouse. The procedure, as outlined in the text, worked very satisfactorily and excellent agreement was obtained among the triplicate standard tubes and also the triplicate assay tubes. The values for glutamic acid were low in all cases and it appears that environmental or cultural effects made conditions unfavorable for glutamic acid elaboration.

10. **The expected relationship** of low nitrogen content accompanied by low glutamic acid content was confirmed.

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Fertilizer Side-Dressing Studies on Sugar Beets in Southern Alberta

K. W. Hill and S. Dubetz[1]

Introduction

Sugar beets have been grown in southern Alberta for twenty-six years. Since the early 1930's growers have been applying 100 pounds of 11-48-0 fertilizer per acre, at the time of seeding. This has become a common practice and is virtually a requirement of the grower's contract. For this reason it is expected that sugar beet farms are quite well supplied with phosphorus. Some barnyard manure has been applied to beet fields since the inception of the industry, but of recent years growers have become more aware of its benefits to the extent that at the present time about twenty percent of the beet land receives manure during the rotation cycle.

Table 1.—Mean Yields in Tons per Acre of Sugar Beets Grown Under Different Fertilizer Side-Dressing Experiments in Southern Alberta in Three Successive Tests During 1948, 1949, and 1950.

		1948			
Amount and kind of fertilizer used for side-dressing	Check No side-dressing		100 lb. 11-48-0	250 lb. 16-20-0	200 lb. 21-0-0
Mean Yield	13.36		13.59	13.97	14.04
		1949			
Amount and kind of fertilizer used for side-dressing	Check No side-dressing		140 lb. 21-0-0	270 lb. 21-0-0	540 lb. 21-0-0
Mean Yield M. S. D. = 0.41	11.96		11.80	12.19	12.70
		1950			
Amount and kind of fertilizer used for side-dressing	Check No side-dressing	230 lb. 21-0-0	460 lb. 21-0-0	150 lb. 33-0-0	300 lb. 33-0-0
Mean Yield M. S. D. = 0.92	12.32	13.57	14.00	13.66	14.34

Outline of Experiments

In 1948, 1949 and 1950, in cooperation with the Canadian Sugar Factories Ltd., and the Consolidated Mining and Smelting Co. Ltd., experiments were undertaken by the Dominion Experimental Station, Lethbridge, to study the effect of applying additional fertilizer as a side-dressing to sugar beets. The effect on the percentage of sucrose as well as the yield of beets has been considered. Suitable fields of sugar beets were selected on different farms, widely scattered throughout the beet growing districts of southern Alberta. Tests were conducted on a total of 33 farms during the three years.

The side-dressing machine provided for four rows of beets to be side-dressed at one time with both sides of each row receiving fertilizer at a depth of three inches. The side-dressing was done soon after thinning and before the first irrigation.

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The 1948 experiment was designed to compare the response of sugar beets to nitrogen and phosphorus fertilizers, and consisted of four treatments. The side-dressing fertilizer applications were:

1. 100 pounds of 11-48-0 per acre
2. 250 pounds of 16-20-0 per acre
3. 200 pounds of 21-0-0 per acre
4. Check (no fertilizer used for side-dressing, but all check plots received the usual 100 pounds of 11-48-0 at the time of seeding)

As in the two following years the treatments were in duplicate on each farm. A treatment plot consisted of eight, twelve or sixteen rows throughout the full length of the farmer's field. During all seasons the plots were sampled, usually during the first week of October, to provide material for sucrose and purity determinations, and all plots were harvested during the

Table 2.—Variance Table Showing Analysis of Yields of Sugar Beets Grown Under Different Fertilizer Side-Dressing Treatments in Southern Alberta in Three Successive Tests during 1948, 1949, and 1950.

	1948		1949		1950	
Variance due to	D.F.	Mean Square	D.F.	Mean Square	D.F.	Mean Square
Treatments	3	1.64	3	4.10**	4	14.07**
Reps. in General	8	0.93	13	1.38*	12	10.44**
Farms	7	59.59**	12	24.04**	11	111.84**
Treatments x farms	21	0.90	36	0.61	44	1.11
Error	24	0.64	39	0.55	48	2.51
Total	63		103		119	

first two weeks of October. The yields were calculated from the total weight of beets grown on the plots, since the production from each plot was delivered separately to the sugar company's receiving station.

The data for the three years are summarized in Tables 1, 2 and 3. The 1950 results from individual farms are shown in Tables 4 and 5.

In 1949, phosphorus fertilizer was not used for side-dressing and the primary objective of the experiment was to determine the most practical amount of nitrogen fertilizer to be used as a side-dressing. The treatments were as follows:

1. 140 pounds of 21-0-0 per acre
2. 270 pounds of 21-0-0 per acre
3. 540 pounds of 21-0-0 per acre
4. Check (no fertilizer used for side-dressing)

An additional purpose of the 1950 experiment was to compare the effectiveness of the two common nitrogenous fertilizers, ammonium sulphate (21-0-0) and ammonium nitrate (33-0-0). The following treatments were used:

1. 230 pounds of 21-0-0 per acre
2. 460 pounds of 21-0-0 per acre
3. 150 pounds of 33-0-0 per acre
4. 300 pounds of 33-0-0 per acre
5. Check (no fertilizer used for side-dressing)

Discussion

Tons of Beets per Acre

The yield results of the 1948 experiment did not show wide differences and statistical analysis did not reveal significant differences between the treatments. However, a careful study during the growing season and of the resulting data indicated that, on some farms where response was most pronounced, the yield increases and improvement in growth due to nitrogen application were too large and too consistent to be ignored. Several farms showed no response, and there was no suggestion of an increase in yield due to phosphorus application on any farm, but two-thirds of the farms

Table 3.—Mean Percentages of Sucrose of Sugar Beets Grown Under Different Fertilizer Side-Dressing Treatments in Southern Alberta in Three Successive Tests During 1948, 1949, and 1950.

1948					
Amount and kind of fertilizer used for side-dressing	Check No side-dressing		100 lb. 11-48-0	250 lb. 16-20-0	200 lb. 21-0-0
Mean sucrose percentage	17.6[1]		17.1	17.2	17.1
1949					
Amount and kind of fertilizer used for side-dressing	Check No side-dressing		140 lb. 21-0-0	270 lb. 21-0-0	540 lb. 21-0-0
Mean sucrose percentage	15.8		15.7	15.7	15.7
1950					
Amount and kind of fertilizer used for side-dressing	Check No side-dressing	230 lb. 21-0-0	460 lb. 21-0-0	150 lb. 33-0-0	300 lb. 33-0-0
Mean sucrose percentage	17.6	17.3	17.0	17.2	17.3

[1] There were no significant differences between the percentages of sucrose resulting from the various treatments in any of the three years.

showed decided increases from the nitrogen fertilizer. For these reasons it was decided the following year that different rates of nitrogen fertilizer alone be used for side-dressing.

The 1949 results established that nitrogen fertilizer can be side-dressed to sugar beets profitably. However, the 540-pound application was the only rate which produced significantly higher yields. Because eight of the thirteen fields were either in fallow or grew a legume the preceding year, it was felt that the lower applications of nitrogen did not have a chance to express themselves. Therefore, the sugar company fieldmen were requested to select fields for the 1950 experiment, which, on the basis of the results of 1948 and 1949, would be expected to respond to additional nitrogen. The selected fields were of relatively lower fertility than in the two former years, the previous crop being sugar beets or cereal grains in all cases. Two different nitrogen fertilizers were used to compare their relative effectiveness.

The results from this experiment showed highly significant yield increases of all treatments over the check plots. The source of nitrogen had no effect on yields; plots treated with ammonium sulphate (21-0-0) or ammonium nitrate (33-0-0) gave essentially the same yields at comparable levels of nitrogen application.

Table 4.—Individual Farm Yields in Tons per Acre of Sugar Beets Grown Under Different Fertilizer Side-Dressing Treatments in Southern Alberta in 1950.

		Amount and kind of fertilizer used for side-dressing				
Grower	Reps	460 lb. 21-0-0	Check No Side-dressing	300 lb. 33-0-0	150 lb. 33-0-0	230 lb. 21-0-0
Schmidt	1	17.23	17.10	17.55	17.37	17.43
	2	17.40	16.51	17.55	17.66	16.88
Barton	1	16.40	12.59	21.33	22.10	18.30
	2	19.07	13.90	17.93	13.40	16.59
Zink	1	19.50	15.77	18.47	17.22	17.28
	2	17.67	13.58	17.12	15.09	15.63
Dueck	1	16.14	9.99	14.98	14.52	13.82
	2	11.62	10.15	12.99	12.55	11.69
Boras	1	14.81	12.14	12.38	12.33	13.98
	2	16.43	16.11	16.11	13.28	16.45
Johnson	1	12.12	10.04	11.53	12.10	14.33
	2	12.04	10.92	15.07	12.86	10.68
Jensen	1	14.19	13.42	15.62	15.20	14.14
	2	17.15	15.81	17.39	16.57	16.34
Thomas	1	18.97	16.53	17.80	20.95	18.00
	2	15.24	12.78	15.58	12.23	12.36
Knoch	1	9.50	9.82	11.94	11.27	10.82
	2	10.36	10.41	11.02	6.70	7.86
Bartz	1	14.37	11.31	13.94	13.39	13.94
	2	14.02	13.71	14.70	15.04	15.45
Dahl	1	10.85	10.88	10.51	10.38	9.65
	2	9.38	9.87	9.46	11.54	9.84
Toth	1	5.45	5.44	6.38	6.74	6.99
	2	6.21	7.02	6.85	7.43	7.29
Mean yield		14.00	12.32	14.34	13.66	13.57

Percent of Sucrose

The mean percentages of sucrose for the different treatments within each experiment were very similar in amount as is indicated in Table 3. A study of the data for the individual farms revealed no tendency for the superiority of any one treatment. The mean percentages of sucrose for the check plots which received no additional fertilizer as a side-dressing were slightly higher for each of the three years. However, this increase seemed to be due to chance variability since it is accounted for almost wholly by two rather high-testing plots for each year, which gave readings up to 19.8 percent sucrose. The duplicates of these plots showed much lower percentages. The contention that this slight superiority in percentage sucrose is not real was borne out also by the statistical analysis. In spite of the large number of replications of these treatments over a wide variety of farms, the statistical reduction of the data showed no tendency for the fertilizers applied shortly after thinning to significantly influence the percentage of sucrose.

Conclusions

The results from these tests indicate that fields which have been intensively cropped without any organic manurial additions may be expected to be low in nitrogen and probably will react favorably to side-dressed applications of chemical nitrogen fertilizer, in addition to 100 pounds of 11-48-0 at seeding time. Such side-dressed applications are not so likely to produce increased yields on fields which have been summer-fallowed or

Table 5.—Individual Farm Percentages of Sucrose of Sugar Beets Grown Under Different Fertilizer Side-Dressing Treatments in Southern Alberta in 1950.

		Amount and kind of fertilizer used for side-dressing				
Grower	Reps	460 lb. 21-0-0	Check No Side-dressing	300 lb. 33-0-0	150 lb. 33-0-0	230 lb. 21-0-0
Schmidt	1	18.4	17.8	17.6	17.8	18.0
	2	16.8	18.0	18.0	15.4	17.8
Barton	1	17.7	17.4	18.0	17.6	17.3
	2	17.8	18.0	17.6	18.4	17.5
Zink	1	16.8	17.4	16.2	16.2	16.6
	2	17.2	17.0	16.6	17.4	16.4
Dueck	1	18.2	18.6	17.6	18.0	17.8
	2	15.0	17.4	17.2	17.2	18.0
Johnson	1	17.0	16.8	17.4	17.0	17.2
	2	17.0	16.2	17.0	17.2	17.6
Jensen	1	16.0	18.0	18.6	17.8	18.4
	2	18.2	18.8	18.2	20.2	18.0
Thomas	1	16.0	18.0	16.6	17.4	16.6
	2	17.4	18.8	17.8	17.8	18.0
Knoch	1	16.2	17.2	16.2	17.2	16.8
	2	16.4	17.2	16.6	14.8	16.4
Bartz	1	17.0	18.4	18.0	18.2	17.8
	2	18.0	17.8	17.2	18.2	17.4
Dahl	1	16.4	17.4	15.2	16.0	14.8
	2	14.4	16.2	15.0	14.6	15.4
Toth	1	17.4	18.2	19.4	18.8	18.4
	2	18.8	16.4	19.4	16.0	18.4
Mean percentage of sucrose		17.0	17.6	17.3	17.2	17.3

manured recently. The most efficient and profitable rate of application seems to be between 200 and 300 pounds of ammonium sulphate or ammonium nitrate at a comparable rate of nitrogen. As was shown in the choice of fields for the 1950 experiment, the sugar company fieldmen appear to be able to select fields, on the basis of crop history, which will respond favorably to side-dressing with nitrogen fertilizer.

There was no evidence to indicate that the amounts of fertilizer, as they were applied early in the season under the conditions of these experiments, affected the sucrose content of the beets.

Fertilizers, Farming Practices and Rotation

EARL Q. MARSING[1]

Sugar beets harvested from the 1951 crops to date in the Nampa-Nyssa District produced an average yield of 21.65 tons per acre and the yield for Canyon County was 23.54 tons per acre.

This yield is obtained by good farming practices, proper rotation and the application of dry and green manure and commercial fertilizers to take advantage of the long growing season.

The commercial fertilizers used in almost every field are phosphate and nitrogen. The average application is 80 pounds to 100 pounds of available phosphate and from 60 pounds to 80 pounds of available nitrogen. However, top tonnage growers are using considerable more nitrogen and some additional phosphate.

Prior to 1940 a very large percentage of the farm land in this area was used in producing feed crops with no application of commercial fertilizer. This practice reduced the original phosphate supply very materially and to a great extent nitrogen was far below the requirements for most row crops.

Since 1937 the trend has been toward row crops with the establishment of better farming practices and the application of fertilizers, but only in recent years have the farmers been convinced of the need for more commercial fertilizers and at this time they would use more if it were available.

The usual practice of high tonnage growers in producing a beet crop at this time is for them to use an application of barnyard or green manure at least once during their rotation plus phosphate and nitrogen annually.

Fall plowing is commonly practiced and in many cases where organic matter is to be plowed down the commercial fertilizers are broadcast prior to plowing, but in other cases it is broadcast on the plowed land and worked into the soil with seed bed tools. This method has advantages from the standpoint of getting an early growth on the leaves.

When lesser amounts of commercial fertilizer are broadcast most farmers apply additional material with side-dressing equipment, usually when beets are three to six inches high.

On the heavier soils in the area fall plowing is almost a must and on lighter soils, except in sand, it is very desirable. However, some growers on lighter soils prefer to clean out feed lots in late winter or early spring and use spring plowing for a better cover on manure and fertilizers applied.

Many farmers are feeding beef or dairy herds hoping, of course, to make a profit on their cattle, but basically to produce manure for their row crop lands. Also the use of green manure crops is becoming quite common.

The most popular green manure crops are alfalfa, first cutting plowed under for late potatoes or third cutting plowed under for beets the following year, Hubam clover planted with grain to plow under wtih the stubble and pea vines plowed under after green pea harvest for late lettuce or seed potatoes.

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[1] Local Manager, Amalgamated Sugar Company, Nampa, Idaho.

A very large percent of the beet growers are using beaters to remove the beet leaves at harvest time. These machines reduce the leaves to fine particles evenly distributed over the ground and they have proven to be a very valuable organic fertilizer.

Some canning corn growers also work their shredded green stalks into the soil as soon as the crop is mechanically harvested. These stalks are valuable as green manure.

Local growers usually will not plant beets more than three consecutive years on the same land and at the end of this period other crops are grown from two to four years before the land goes back to beets.

This practice is encouraged by the Amalgamated Sugar Company for the purpose of maintaining organic matter in soils and also as a means of combatting a possible infestation of sugar beet nematode which has never yet been found in the Boise Valley, but we believe that if and when it appears a good rotation program will help in preventing a rapid spread.

Soil Conditions Affecting Infiltration of Water and Root Development of Crop Plants

L. D. Doneen and D. W. Henderson[1]

Poor water penetration in California soils has become one of our major irrigation problems, and is considered by some authorities to be the foremost problem in plant-soil-water relations in our state. A water penetration problem at any given location may be caused by excessive adsorbed sodium, high clay content, or compaction. All these factors will be discussed, with emphasis on compaction by farm machinery.

It has long been realized that dense or heavy layers in the soil will prevent rapid percolation of water. As early as 1902 Mills (9)[2] described hard soil layers at the depth of plowing as "plowsoles" or "irrigation hardpans" which interfere with penetration of irrigation water in cultivated citrus groves. Since that time there has been considerable work on the problem, and it has been suggested that roots may not develop readily in these plowsoles. More recently Huberty (8) concluded that dense layers form most readily in soils with a wide range of particle sizes such as gravelly loams. Such investigations have been one of the contributing factors in the reduction of cultivation or working of the soil to a minimum, and many orchardists have adopted the practice of noncultivation.

With row crops such as sugar beets, considerable manipulation of the soil is necessary for preparation of the seed bed, weed control, furrowing for irrigation and harvesting. These operations should be kept at a minimum (5), but many of them must be performed under weather and soil moisture conditions not conducive to maintenance of good soil structure.[2] Recognizing that soil structure influences the rate of infiltration of water into soil, the Irrigation Division of the University has made preliminary investigations of some of the factors which influence physical properties of soil importance in water penetration and root development. These investigations have been carried out in several areas of the state, and have dealt with soils ranging in texture from very sandy soils to adobe clays and with many field crops, including sugar beets.

For purposes of discussion it is convenient to classify problem soils according to the cause of poor structure. It has been found that poor structure may be physical or chemical in origin, and that it may be present in soils in their natural state or may be produced by farming operations such as tillage and grazing. Poor structure is sometimes reflected in abnormally high apparent density, but there are problem soils whose densities are relatively low. Such soils have relatively high total porosity but a small percentage of large pores which apparently are important in rapid conduction of water (2) and root development. This phase of the problem is receiving further study.

Such a classification indicates that soil density is not a good criterion for studying soil structure, and this is true even for a given soil. This point is illustrated in Figure 1 in which infiltration rates of laboratory packed

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[2] Numbers in parentheses refer to literature cited.

samples are plotted against density. At relatively low densities a small increase in density results in a large decrease in infiltration rate, while at high densities an increase in density results in only a slight decrease in the infiltration rate. Furthermore, the infiltration rate will differ widely in soils of different texture at the same density. Similar results have been reported by Bodman (4). However, density data have been included for soils in Tables 1, 2 and 3 to show how they fit into the classification used.

A specially designed sampler was developed for taking essentially undisturbed soil samples for laboratory determination of soil density and infiltration rates. The sampler utilizes paraffined cardboard cylindrical

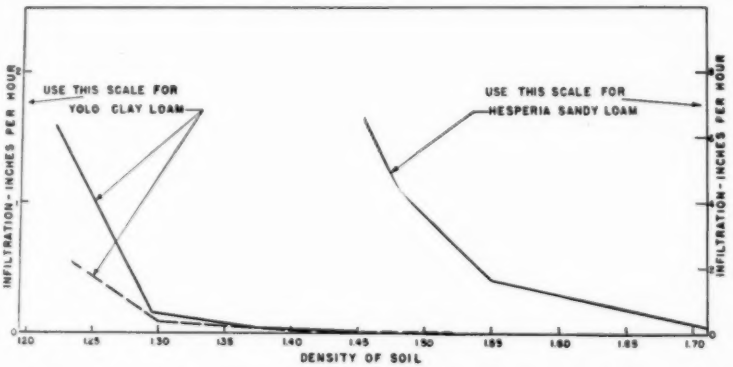

Figure 1. Effect of density of soil on the infiltration rate of irrigation water.

drug cartons 3½ inches in diameter and 7½ inches high for the inside liner and sample container. The full depth may be used or a sample can be sliced into any desired increments of depth (7).

Soils with poor structure are difficult to distinguish in the field, particularly if the soil is moist. When dry they are very hard and may be detected by an experienced observer. The authors at present conclude that making infiltration tests is the simplest way to detect compact layers occurring in normally friable soils. Such tests can be made either in the field or with undisturbed soil samples in the laboratory.

The present investigation is concerned not only with the infiltration of water into compact soils but also with the effects of poor soil structure on root development which is likewise very important in irrigation practice. The effects of poor soil structure on root development of sugar beets have been discussed by Baver and Farnsworth (3) and by Rietberg (12). Pendleton (11) compacted Chehalis and Willamette soils to a density of 1.95 gms./cc. and no beet roots penetrated them. At 1.8 the main taproot usually penerated the soil, but few feeder roots were formed.

[3] The term soil structure as used in this paper refers to pore size distribution rather than to shape of soil aggregates. A soil is considered to have good structure if it has an adequate percentage of large pores so that water and roots can penetrate readily.

High Density Soils

Soils of high density in their natural state have been reported by Veihmeyer and Hendrickson (13). They found densities of 1.8 to 1.9 in subsoils of the Bale series and some "primary chaparral" soils. Roots of several species of plants did not absorb water from these compact subsoils, and laboratory experiments with artificially packed soils indicated that plant roots were unable to penetrate the soil at that density. Similar experiments with other soils showed that sunflower roots would not enter sands at densities above 1.75, and the limiting density for root penetration varied from 1.46 to 1.63 for clay soils (14). Veihmeyer and Hendrickson concluded that soil density alone cannot be taken as the critical factor, and that the size of individual pores is probably important.

Hardpans or cemented layers would be placed in this category. Unless broken up they are considered impervious to water and roots. The authors believe that, except for hardpans, subsoils of high density are not commonly found in the alluvial soils of California.

Mechanically produced high soil density is a result of tillage operations and was first noted in California as plowsoles formed in citrus groves (9) and orchards from frequent tillage, usually with the moldboard plow. Old

Table 1.—Distribution of Soil Density with Depth.

Potato field[1]		Cotton field[2]		Sudan grass field[3]			
Depth	Density	Depth	Density	Depth	Density	Depth	Density
in.	gm/cc	in.	gm/cc	in.	gm/cc	in.	gm/cc
1-3	1.63	6-8	1.58	2-4	1.46	2-7	1.60
3-5	1.74	8-10	1.69	4-6	1.52	7-12	1.70
5-7	1.70	10-12	1.67	6-8	1.53	12-18	1.50
7-9	1.67	12-14	1.67	8-10	1.52	18-24	1.37
9-11	1.68	14-16	1.67	10-12	1.52		
11-13	1.66	16-18	1.61	12-14	1.50		

[1] Hesperia sandy loam—average of eight samples taken in bottom of furrow between potato rows. First inch discarded.
[2] Hesperia sandy loam—average of six samples taken between cotton rows. Surface six inches discarded because of loose condition of the soil from cultivation.
[3] Yolo clay loam—in the left column average of eight samples taken at random from the field; columns on the right are for an average of four samples taken from the irrigation check having the lowest infiltration rate (0.1 inch per hour) of any in the field.

grainlands often have plowsoles and when the land is placed under irrigation these can be troublesome until they are broken up. The senior author has examined many of the grainland plowsoles when first converted from dryland production to irrigation of sugar beets. In these fields water ponded in local depressions or at the end of the furrows, and the sugar beets "drowned out." Examination showed that the plowsole prevented normal penetration of irrigation water with water frequently standing in the furrow for several days. The saturated soil above the plowsole caused an anaerobic condition, resulting in rotting of the root system and death of the plant. In some California areas the need for breaking up grainland plowsoles occurring at a depth of 5 to 7 inches below the soil surface is the principal cause of the general practice of plowing at least 12 inches deep for sugar beets (5).

In recent years an overall study of water penetration problems has shown a general deterioration of soil structure. This condition is indicated in most cases by the compaction of soil from near the soil surface to a depth

of 18 to 24 inches, rather than the relatively thin plowsoles described by most earlier investigators. Apparently the development of heavy farm machinery and tractors has contributed to the formation of the compacted surface layer in soils. This fact is illustrated by the data in Table 1. The soil of the potato field had a high density from 3 to 7 inches below the surface, and may be considered a plowsole. The samples were taken in furrows between 8-inch potato beds, and if the depths of the samples are referred to a leveled soil surface the densest layer would occur at about the 6- to 10-inch depth—a depth characteristic of plowsoles. However, the soil also had a relatively high density to depth of 13 inches (17 inches referred to the leveled soil surface). The soil from the cotton field was uniformly high in density to a depth of 16 inches. In the heavier soil of the Sudan grass field there was a uniformly high density to a depth of 14 inches. However, in a portion of the field with an extremely low rate of water penetration very high density occurred at the 7- to 12-inch depth, and the density was relatively high to a depth of about 18 to 24 inches.

In the summer of 1949 the authors' attention was called to several alfalfa fields in Kern County in which regularly spaced strips about one foot in width produced only small plants approximately 3 or 4 inches high,

Table 2.—Growth of Alfalfa and Soil Density[1]

Field	Alfalfa growth	Depth	Number samples	Density
	in.	in.		gm/cc
1	3	0-12	10	1.83
		12-24	4	1.72
		6-12	28	1.98
	18	0-12	10	1.68
		12-24	4	1.69
		6-12	30	1.69
2	3	6-12	28	1.88
	18	6-12	28	1.78

[1] Data obtained by J. D. Axtell, formerly Farm Adviser, Kern County, California.

while plants in the areas between these strips grew to a normal height of about 20 inches. The soil densities in areas of poor and normal growth in two typical fields are given in Table 2. The soils in the poor strips were higher in density, especially in the 6- to 12-inch depth. These fields were merely disked after a crop of potatoes or cotton before being seeded to alfalfa, and it was evident that the dense strips were between the rows of the previous crop. The soil compaction resulted from cultivation, furrowing and harvesting operations.

Subsequently, many fields were visited where water penetration had become a problem. In all cases the grower reported that water penetration had formerly been adequate. Many of these fields are now irrigated three or four times as frequently as in the past, with the water held on the field much longer at each irrigation. The results of infiltration rates and soil densities determined on core samples from representative fields are reported in Table 3. The moisture equivalents (a laboratory estimation of field capacity) are given as a measure of the waterholding properties of the soils, and the footnotes list the soil type.

Samples 1 and 2 show difference in compaction by depth. A reduction of only 0.11 gms./cc. in density caused an increase in the infiltration rate of more than 200 percent. This soil is from the same potato field reported on in Table 1. Water stood in depressions and the ends of furrows for two or three days before soaking into the soil. Examination of the soil profile under the beds and furrows indicated that very few potato roots penetrated more than 2 or 3 inches below the bottom of the furrow. The soil density was 1.74 at this depth (see Table 1), and it is apparent that this soil was sufficiently compact to limit root development. The yield of this field was about half that of adjoining fields where compaction was not a problem, and there was an appreciably smaller percentage of U. S. No. 1 grade.

Samples 3 and 4 were taken from one side of the same field in an unplanted area where farm equipment was turned repeatedly in cultivating the field. The soil was of high density and low infiltration rate to a depth of at least 14 inches, apparently the result of farm machinery passing over the soil surface. An infiltration rate of 3 to 4 inches per hour is not unusual in these soils when they have good structure.

Samples 5 and 6 are also Hesperia sandy loam, but of a lighter phase as indicated by the moisture equivalent. Although the densities of this soil are as high as that of samples 1, 3 and 4, the infiltration rate averages 0.75 inch per hour, and excellent potatoes were produced in the field. These data emphasize the fact that soil density alone is not a sensitive criterion of the infiltration rate.

Samples 7 and 8 were obtained from an alfalfa field reported on in Table 2. The samples were taken during the third season after planting the crop. The alfalfa had not been killed out in the compacted strips, but the plants were still much smaller. These data are evidence that compaction in the strips is somewhat less than that at the time the crop was established At present the infiltration rates of these samples is nearly half that of the normally producing areas. These changes may be the result of many old root channels formed by young alfalfa plants which died out in the normal aging of the stand.

Samples 9 and 10 are from a barley field which received one irrigation when the crop was about half grown. This field strikingly showed the strips as described for the alfalfa field, but the strips were 18 to 20 inches wide, suggesting that the compacted strips were caused by a crawler type tractor. Sample 9 was taken from the compact area where water penetration had been so poor that barley plants were nearly dead from lack of water. Sample 10 was taken from an area of barley growing normally. Although the densities differed only slightly, the infiltration rate of the soil from the "normal" area is three and one-half times that of the compacted strips.

Poor water penetration in old irrigated pastures has been called to the attention of the authors. Since water penetration was no problem at the time these pastures were planted, the difficulty is apparently due to soil compaction caused by grazing when the soil is too wet. In some cases stock are left in the pasture during irrigation. Samples 11 and 12 were taken from one such pasture. Infiltration rates were measured by determining the rate of drop of the water surface in the cylinders. These cores simply

did not transmit any water, and the apparent infiltration rate of 0.005 inch per hour can be accounted for by evaporation of water from the cylinders, since the bottoms of these samples remained relatively dry at the end of several days. The condition is so severe that water grass and other water-loving weeds crowd out pasture plants.

All of the above examples were taken from Kern County.

Samples 13 to 20 listed in Table 3 were taken in San Joaquin County and are examples of difficulties with heavier soil types. The samples were taken in tomato fields in the bottom of irrigation furrows, a level 5 or 6 inches below the ground surface before the beds were formed. Samples 13

Table 3.—Soil Densities and Rate of Water Infiltration on Undisturbed Soil Cores.

Sample number[1]	Depth sample	Number tests made	Infiltration	Soil density	Moisture equivalent
	in.		in./hr.	gm/cc	%
1	8-15	7	0.162	1.73	10.3
2	19-25	6	0.495	1.62	11.3
3	0-7	1	0.162	1.73	9.1
4	7-14	1	0.240	1.75	10.5
5	0-7	1	0.780	1.72	6.6
6	7-14	1	0.720	1.73	5.9
7	0-6	5	0.408	1.80	
8	5-12	3	0.875	1.75	
9	5-12	3	0.208	1.73	
10	5-12	3	0.764	1.71	
11	0-6	1	0.006	1.38	25.5
12	6-12	1	0.004	1.46	25.4
13	0-6	2	0.052	1.49	24.3
14	6-12	1	0.018	1.52	24.3
15	24-30	1	1.370	1.34	17.4
16	0-5	1	0.030	1.61	21.3
17	5-10	1	0.041	1.59	21.3
18	10-16	1	0.042	1.45	17.4
19	0-7	1	0.036	1.54	25.8
20	7-14	1	0.084	1.49	25.8
21	2-7	4	0.031	1.60	21.0
22	7-12	4	0.012	1.70	22.2
23	12-18	4	0.017	1.50	26.4
24	18-24	4	0.660	1.37	27.1

[1] Nos. 1 and 2. Hesperia sandy loam. Core samples taken the spring following potatoes after the soil was plowed but before planting cotton.
Nos. 3 and 4. Hesperia sandy loam. Adjacent to field where samples 1 and 2 were collected. An area between power poles cultivated only for weed control.
Nos. 5 and 6. Hesperia sandy loam. Cores taken from bottom of furrow in a potato field.
Nos. 7 and 8. Exeter sandy loam. 7, small alfalfa plants from tractor compaction; 8, samples about 15 inches from No. 7 where large alfalfa plants were growing vigorously.
Nos. 9 and 10. Delano loamy soil. 9, in barley field where strips showed deficiency of soil moisture; 10, about 2 feet from sample 9 where barley was normal and showing no water deficiency.
Nos. 11 and 12. Cajon clay loam. An old irrigated pasture.
Nos. 13, 14 and 15. Rincon clay. Core samples taken from bottom of irrigation furrow in a field of tomatoes.
Nos. 16, 17 and 18. Sorrento silty clay. Core samples taken from the bottom of the irrigation furrow in a field of tomatoes.
Nos. 19 and 20. Stockton clay adobe. Samples taken from the bottom of an irrigation furrow in a field of tomatoes.
Nos. 21, 22, 23 and 24. Yolo clay loam. Samples taken from a Sudan grass field.

and 14 were taken from the first food of a dense layer of Rincon clay extending to a depth of about 22 inches. Sample Sample 15 was secured from the friable soil below this depth. The friable soil had an infiltration rate seven and one-half times that of the compacted layer. Samples 16, 17 and

18 are from a soil classified as Sorrento silty clay which has a dense layer at least 16 inches in depth with a very low infiltration rate. Probing and digging indicated that the layer was approximately 22 inches thick. Samples 19 and 20 were taken in a Stockton clay adobe. The soil is very dense, considering its heavy texture, and the infiltration rate is very low. Below the 24-inch depth there was an extremely heavy clay (moisture equivalent = 39) with a density of 1.68. Apparently this soil is similar to the dense subsoils reported by Veihmeyer and Hendrickson (13).

Excavations were made in all the tomato fields and the roots were examined. A heavy mass of both large and small roots was found in the surface 8- to 10-inch depth which included the cultivated layer plus the soil from the furrows. Only a few slender roots penetrated the dense layers. There was no branching in the compact zone, but there was considerable branching in the more friable soil below.

Samples 21, 22, 23 and 24 were taken from a field of the University Farm at Davis, and indicate compaction to a depth of 18 inches with a resulting low infiltration rate. Sample 24, taken from below the 18-inch depth, is only slightly more dense than is normal for this soil.

These examples are from only a few of many investigated during the past two years. Although Table 3 reports only on light and heavy soils, dense layers have been found in loam soils as well. The condition does not predominate in any soil textural class.

Additional studies on root development in compact Yolo soil listed as sample 21 in Table 3 were made with 60 core samples 4 inches in depth. Two inches of loose sieved soil from the same location were placed on top of these cores.

They were divided into groups of 12 with each group planted to one of the following crops: Beans, tomatoes, onions, sunflowers and wheat. After the plants had reached a size large enough to have a well developed root system, the containers were removed and root systems in the dense soil studied. It was found that none of the crops had any appreciable number of roots in the compact soil, with the exception of wheat, which had approximately 25 percent of the total root system by weight growing in the compact layer. Wheat roots have a smaller diameter than any of the other plants studied. The occasional roots of plants other than wheat found in the dense layer usually followed an old root channel, and sometimes grew through the partly decomposed old root. Figure 2 illustrates the root development of beans. The roots grew between the container and the dense soil. They were flattened so that they were four to five times as wide as they were thick. All branching of the roots was parallel to the surface of the dense soil on the sides as well as on the bottom of the container.

No quick and easy solution has been found for the problems arising from compacted soils caused by farm operations. The most intelligent approach seems to be prevention of compaction as much as possible by careful soil management. In this connection, the moisture content at which a soil is worked is popularly believed to be important. A study of the effect of the passage of a wheel tractor over Hesperia sandy loam at various soil

moisture content has been made, using the infiltration rate of the soil as a criterion of compaction. The results of this experiment are to be published in detail elsewhere (7). The authors concluded, however, that the drier the soil the smaller the decrease in infiltration rate, although there was a significant decrease even when the surface 6 inches of soil was below the wilting percentage.

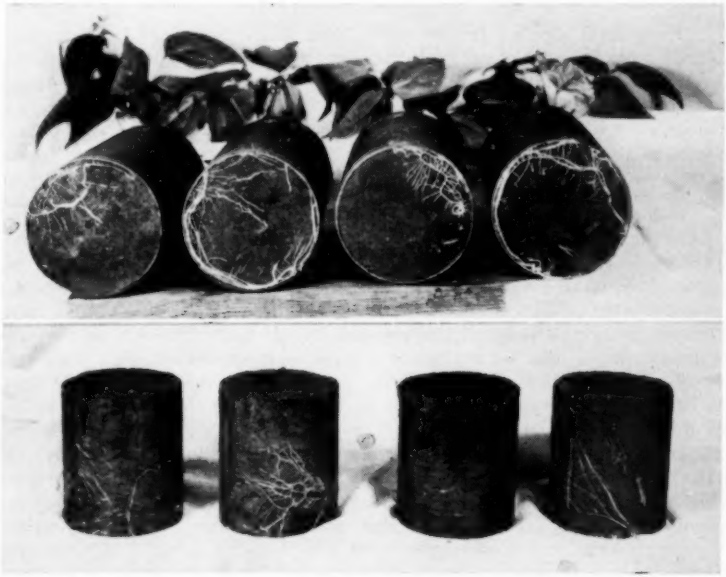

Figure 2. Root development of beans in undisturbed soil samples from a field having a soil density of 1.60.

Soils with low volume weight

Low volume weight soils naturally occurring under certain conditions may have extremely poor structure preventing normal root development and limiting water penetration. Such a soil, classed as Tulare clay, occurs in the lower part of the Tulare lake basin. The area has been extensively farmed to winter barley, and summer crops are failures. Investigation in this area, where cotton was growing, indicated the roots were limited to the cultivated soil. Below this friable surface layer was a tight, plastic clay about 20 inches in depth which rested on loam soil. The density of the soil from this tight clay layer is about 1.1 to 1.2, which is considered low. The clay content averages about 70 percent, with most of the remaining percentage as silt. The moisture equivalent averages about 50 percent. There is no essential difference between the cultivated layer and the tight subsoil in clay and silt content or moisture equivalent. During the summer most of the taproots of the cotton plant will slowly penetrate through this dense layer, and once through they send out many branch roots. These cotton plants are

so stunted they rarely reach a height of more than 10 to 15 inches, and bolls are set so late in the summer they do not mature. In about the third or fourth year of summer cropping normal cotton will be produced, or if the soil is broken up and allowed to dry as in old irrigation ditches, normal plants are produced the first year. There is a great deal of shrinking on drying and a soil of crumb structure is formed which water and roots can penetrate.

These tight soils are in the bottom part of the lake bed where the fine materials from the river waters settled out. Apparently no large pores were formed. All the tight subsoils need is a few cycles of wetting and drying and an improved soil structure will result. The authors believe similar conditions exist in some of the ricelands of the Sacramento Valley. Some claypans are also of low density but nearly impervious to roots and transmit water slowly.

Sodium-dispersed soils usually have a low density. As the sodium content of the soil increases there is a tendency toward dispersion of the colloidal fraction of the soil, destroying structure and eliminating large voids or pores. When this condition is reached, the soil becomes quite impermeable to water. This situation occurs in the sodium saline and alkali soils. Such soils are usually obvious to investigators in the field, either from the salt accumulation on the soil surface or a dark or black discoloration from the sodium alkali—"black alkali." If excessive sodium is suspected, simple field or laboratory tests can be made. Some of the sodium-dispersed soils caused by the use of an irrigation water containing a high percentage of sodium salt are not so easily detectable. Doneen (6) and Axtell and Doneen (1) have reported a deterioration of soil structure and a greatly reduced permeability of the soil from the use of these high sodium waters. There are no obvious symptoms in the field to distinguish this cause of low infiltration rates from some of the others discussed above, and at present there are no simple laboratory tests. The simplest method, without involving a great deal of laboratory analysis, is to make an infiltration test with a high calcium water. The present method used by the authors is to make an infiltration test with a water containing 10 to 20 milligram equivalents per liter (860 to 1,720 parts per million) of gypsum (calcium sulfate). If the infiltration rate increases as the gypsum water penetrates the soil, it is usually sodium-dispersed.

Upon drying, sodium-dispersed soils are hard and are difficult to distinguish from the compacted soils mentioned above. A sodium-dispersed clay soil has a tendency to crack on drying, but with the compact soil little shrinkage takes place. In the sandy soil where little cracking is in evidence, it is very difficult to distinguish between sodium-dispersed and compacted soil. The effect of sodium-dispersed soils on root development has not been fully investigated, but observations have indicated that most plants will develop roots under this condition.

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The Effect of Alfalfa on the Yields of Non-Leguminous Crops in a Rotation[1]

ROBERT GARDNER AND D. W. ROBERTSON[2]

Alfalfa is highly valued as a feed crop and has a good reputation as a "soil builder," but not all people agree that there is a net gain in soil fertility from alfalfa in a crop rotation if it is harvested for hay and no manure returned to the soil. Some have advanced the theory that the observed benefits from alfalfa are due to its solvent effect on mineral nutrients and a consequent increase in their availability to plants. Others attribute the benefits to a net contribution to the soil nitrogen supply.

Recently, pronounced benefits from alfalfa in a rotation have been obtained in an experiment now in progress on the Colorado A & M College Agronomy Farm. Information has also been obtained which indicates what the probable major reasons for the benefits are and what influence alfalfa in a rotation may have on need for fertilizers.

Table 1.—The Effect of Rotations on the Yield of Beets Under Different Fertilizer Treatments (Tons Per Acre)

	A. Beets after Corn							
	1950				1951			
	No Fert.	P	N	NP	None	P	N	NP
8-Year	12.83	16.68	14.00	17.42	13.49	15.54	12.32	15.09
5-Year	7.69	13.22	12.21	14.93	8.24	8.97	12.77	18.21
Difference	5.14	6.46	1.79	2.49	5.25	6.57	—0.45	—3.12
	B. Beets after Wheat							
8-Year	11.33	14.37	12.52	17.05	8.87	12.68	10.21	18.95
5-Year	7.08	10.38	10.46	17.85	8.82	8.77	10.91	17.52
Difference	4.25	3.99	2.06	—0.80	— .05	3.91	—0.70	1.43

Test Started in 1935

The experiment, which was started in 1935, consists of a comparative study of two rotation systems differing initially from each other only in the occurrence of three crop years of alfalfa in one rotation and not in the other. Later, when phosphate was applied, the average rate was less in the alfalfa

Table 2.—The Effect of Rotations on Yield of Sugar Under Different Fertilizer Treatments (Lbs. Per Acre).

	A. Beets after Corn							
	1950				1951			
	No Fert.	P	N	NP	None	P	N	NP
8-Year	4,703	6,025	5,291	6,144	4,737	5,168	3,572	4,487
5-Year	2,886	3,830	4,566	5,456	2,727	3,078	4,058	6,283
Difference	1,817	2,195	725	688	2,010	2,090	—486	—1,796
	B. Beets after Wheat							
8-Year	4,273	5,311	4,688	6,318	3,016	4,420	3,094	5,854
5-Year	2,652	4,064	3,976	6,970	3,128	3,044	3,555	5,826
Difference	1,585	1,247	712	—652	—112	1,376	—460	28

[1] Contributed from the Agronomy Section Colorado Agricultural Experiment Station, Fort Collins, Colo. Published with the approval of the Director of the Colorado Agricultural Experiment Station as Scientific Series Paper No. 385.

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rotation since applications were made to only 2 plots out of 8 each year instead of to 2 plots out of 5 as in the other rotation. The sequence of crops, exclusive of alfalfa, is corn, sugar beets, wheat, sugar beets and barley

Table 3.—The Effect of Rotations on the Yield of Beet Tops Under Different Fertilizer Treatments (Tons Per Acre).

	A. Beets after Corn							
	1950				1951			
	No Fert.	P	N	NP	None	P	N	NP
8-Year	17.64	18.79	18.62	22.77	13.39	14.34	20.01	18.21
5-Year	8.08	8.58	13.07	13.40	6.53	6.29	18.64	14.69
Difference	9.56	10.21	5.55	9.37	6.86	8.05	1.37	3.52
	B. Beets after Wheat							
8-Year	10.87	10.45	13.58	12.50	9.94	8.40	17.29	17.14
5-Year	7.02	5.55	12.09	10.78	5.95	6.05	14.93	13.65
Difference	3.85	4.90	1.49	1.72	3.99	2.30	2.36	3.49

in both rotations. A complete cycle of the rotation without alfalfa is, therefore, five years and, in the rotation which includes alfalfa, eight years. In the eight-year rotation alfalfa is planted with the barley but no alfalfa is harvested the first year of growth.

The alfalfa stubble and third crop of hay, varying from ½ to 1 ton per acre, is plowed under in late fall of the third crop year. The rotations are in duplicate and all crops on each rotation are produced each year.

Table 4.—The Effect of Rotations on the Yield of Cereals Under Different Fertilizer Treatments (Bu. Per Acre).

	Corn							
	1950				1951			
	No Fert.	P	N	NP	None	P	N	NP
8-Year	74.1	64.0	65.7	63.5	39.9	50.2	42.4	45.4
5-Year	42.4	50.2	46.9	67.7	28.1	35.0	35.8	43.6
Difference	31.7	13.8	18.8	—4.3	11.8	15.2	6.6	1.8
	Wheat							
8-Year	30.6	38.3	24.4	41.2	38.9	41.0	40.8	42.3
5-Year	23.5	24.2	27.0	30.1	26.7	28.1	35.0	39.4
Difference	7.1	13.1	—2.6	11.1	12.2	12.9	5.8	2.9
	Barley							
8-Year	51.2	62.1	74.9	68.3	44.8	47.6	65.6	74.6
5-Year	37.2	36.1	44.3	70.6	31.7	30.8	51.9	69.9
Difference	14.0	26.0	30.6	—2.3	13.1	16.8	13.7	4.7

No manure, except the small third cutting of alfalfa added as green manure before each corn crop in the 8-year rotation, has been added to either rotation. No commercial fertilizers were added during the first 7 years of the experiment. Since that time, the study has been conducted as a split plot experiment and phosphate has been added to one-half of each sugar beet plot annually at the rate of 54 pounds of P_2O_5 per acre until 1949 and 86 pounds per acre since that time. In 1950, the experiment was divided into quarters and nitrogen was added at the rate of 66 pounds per acre to two of the four subdivisions of all plots in the experiment. The same two subdivisions were fertilized again in 1951 at the rate of 100

pounds of nitrogen per acre. One quarter has received no fertilizer, one phosphorus only, one nitrogen only and the fourth both nitrogen and phosphorus.

Alfalfa and Fertilizer Contributions to Yields[2]

Some of the major results of the experiments are summarized in the tables included in this paper. Tables 1 to 4 show yields per acre for 1950 and 1951 of all crops in both rotations under the different fertilizer treatments. Table 5 shows the increases in yields of all crops which can be attributed to effects of alfalfa. The increases were calculated by subtracting the 5-year rotation yields from the 8-year rotation yields. Approximate cash values of the increases are also shown in Table 5. Table 6A and 6B show the comparative increases due to fertilizers on each rotation and the cash values of the increases. The increases were calculated by subtracting the yields of the unfertilized plots from comparable yields of the fertilized plots.

Table 5.—Increased Yields and Cash Returns Due to Alfalfa in a Crop Rotation. (Per acre value for each crop).

	Increased Yields (tons and bu.)				Increased Cash Returns[1]			
	No Fert.	P	N	NP	None	P	N	NP
Beets (1st)	5.20	6.52	0.67	—0.32	$62.40	$78.24	$ 8.04	$—3.84
Beets (2nd)	2.15	3.95	0.68	0.32	25.80	47.40	8.16	3.84
Corn	21.75	14.50	12.70	—1.25	38.28	25.52	22.35	—2.20
Wheat	9.65	13.00	1.60	7.00	20.26	27.30	3.36	14.70
Barley	13.55	21.40	22.15	1.20	17.21	27.18	28.13	1.52
			Total (5 acres)		163.95	205.64	70.04	14.02
			Average increase per acre		32.79	41.13	14.01	2.80
			L.S.D. = 30.89 at 1 pct. point					

[1] Values based upon $12.00 per ton of beets, $1.76 per bu. corn, $2.10 per bu. wheat, $1.27 per bu. barley.

Table 6A and 6B show the comparative increases due to fertilizers on each rotation and the cash values of the increases. The increases were calculated by subtracting the yields of the unfertilized plots from comparable yields of the fertilized plots.

Table 6A.—Increased Yields and Cash Return Due to Fertilizers in 8-Year Rotation—Two Year Average.

Increased Yields			Increased Cash Returns		
P	N	NP	P	N	NP
		Beets after Corn (Tons)			
3.95	0.00	3.20	$47.40	$ 0.00	$38.40
		Beets after Wheat (Tons)			
3.43	1.27	7.90	41.16	15.24	94.80
		Corn (Bu.)			
0.10	—2.95	—2.55	0.18	—5.19	—4.49
		Wheat (Bu.)			
4.90	—2.15	7.25	10.29	—4.52	15.23
		Barley (Bu.)			
6.85	22.25	23.45	8.70	28.26	29.78
		Total (5 acres)	107.73	33.79	173.72
		Fertilizer Cost	14.00	57.20	71.20
		Total Minus Fertilizer Cost	93.73	—23.41	102.52

The comparative yields for the two rotations with no fertilizer are shown in the lefthand columns of the 1950 and 1951 figures of Tables 1

[2] For the sake of simplicity, the statistical analyses are omitted. The major effects presented are highly significant.

to 4, headed "No Fert." These yields are consistently higher in the 8-year than in the 5-year rotation. From this column alone, no specific cause can be assigned to the differences other than that they are due to alfalfa. However, when it is further observed in the other columns that the 8-year rotation gave the greatest response to phosphate alone, the 5-year rotation to nitrogen alone and to nitrogen plus phosphorus, there is good evidence in support of the following conclusions:

(1) That the unfertilized plots in both rotations were markedly deficient in available phosphorus; (2) that the 5-year rotation was much more deficient in nitrogen than the 8-year rotation, and (3) that nitrogen contributed by the alfalfa was the principal cause of the greater yields from the 8-year rotation. The visual appearance of the crop and crop analysis have supported these conclusions.

Table 6B.—Increased Yields and Cash Returns Due to Fertilizers in 5-Year Rotation—Two Year Average.

Increased Yields			Increased Cash Returns		
P	N	NP	P	N	NP
		Beets after Corn (tons)			
1.63	4.53	8.63	$19.56	$54.36	$103.56
		Beets after Wheat (tons)			
1.63	2.47	9.74	19.56	29.64	116.88
		Corn (bu.)			
5.60	—0.35	7.70	9.86	—0.62	13.55
		Wheat (bu.)			
1.05	5.90	9.40	2.21	12.39	19.74
		Barley (bu.)			
—0.01	13.65	35.80	—0.01	17.34	45.47
		Total (5 acres)	51.18	113.11	299.20
		Fertilizer cost	14.00	57.20	71.20
		Total Minus Fertilizer Cost	37.18	56.91	228.00

Table 5 shows the economic importance of alfalfa in the rotation. In the lefthand half of the table the yield differences which can be attributed to alfalfa are given and the right half portion shows estimated cash values of these differences under the various fertility levels. It is evident from this table that at high fertility levels resulting from nitrogen and phosphorus fertilization the benefits from alfalfa were much less than where no fertilizer was applied or where phosphorus only was applied.

The greatest difference between rotations occurred where phosphorus only was applied and the least difference occurred where nitrogen and phosphorus were used in combination. The difference between the two rotations was small and statistically insignificant when both rotations received nitrogen and phosphorus. In all other cases the 8-year rotation gave significantly greater cash returns.

The data in Tables 6A and 6B summarize the increased yields obtained at different nitrogen and phosphorus levels and the cash values of the increases. There was a net loss from the use of nitrogen alone on the 8-year rotation when the cost of fertilizer was considered. The profit from phosphorus alone on the 8-year rotation was significantly greater than on the 5-year rotation. Nitrogen alone or the combination of nitrogen and phosphorus was profitable in the 5-year rotation.

The data, as a whole, indicate that (1) on land which is not well-fertilized with nitrogen carrying materials, alfalfa will contribute materially to crops which follow it in a rotation; (2) alfalfa in a rotation does not minimize the necessity for mineral fertilizers; (3) where large quantities of nitrogen fertilizers are used the contribution of alfalfa is less important.

Irrigation Practice as it Affects Fertilizer Requirement, Quality and Yield of Sugar Beets[1]

D. Boyd Archibald and Jay L. Haddock[2]

Approximately 85 percent of the sugar beet acreage in the United States is under irrigation. "Water turn" and "share holdings" rather than need frequently have controlled the time and quantity of water applied to the sugar beet crop. Since irrigation practice is so important in sugar beet culture and since the economical use of water is becoming increasingly important for all crops, it is desirable that growers become familiar with the effects of various irrigation practices on fertilizer requirements, quality and yield of sugar beets.

Results from experiments conducted in 1946 and 1947 (1)[3] at the Utah Agricultural Experiment Station showed marked differences in yield and quality of sugar beets among four irrigation treatments studied. The results of these experiments indicated the need for further study on the effect of irrigation practices as they affect fertilizer requirements, quality and yield of sugar beets. Such a study was made possible in 1948 through the cooperative efforts of the following organizations: Utah-Idaho Sugar Company; Amalgamated Sugar Company; Sugar Beet Development Foundation; Utah Agricultural Experiment Station, and the Bureau of Plant Industry, Soils and Agricultural Engineering of the U. S. Department of Agriculture.

Experimental Procedure

An experiment was designed to study the relationship of irrigation practice and soil fertility on yield and quality of sugar beets. This experiment was placed near Garland, Utah, on Millville sandy clay loam with a randomized split-plot design. Six irrigation regimes constituted the main plots. Superimposed on each irrigation plot were six fertilizer treatments. The irrigation treatments are symbolized and described as follows:

W_1—Moist all season (10 sprinkle irriagtions).
W_2—Moist all season (9 furrow irrigations).
W_3—No irrigation until July 20; moderately moist remainder of season (5 irrigations).
W_4—Moderately dry all season (2 sprinkle and 4 furrow irrigations).
W_5—Moist until July 29; no irrigation thereafter (2 sprinkle and 1 furrow irrigations).
W_6—Moist until August 14; no irrigation thereafter (2 sprinkle and 3 furrow irrigations).

Commercial fertilizer was side-dressed four inches below the soil surface and six inches to the side of the row June 26. Manure was applied prior to seeding and disked into the soil.

Soil moisture conditions were followed by means of tensiometers and resistance blocks. It is evident from the resistance block readings shown

[1] Contribution from the Division of Soil Management and Irrigation, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture, in coopertion with the Utah Agricultural Experiment Station, Logan, Utah.

[2] Work Unit Conservationist for the Soil Conservation Service at American Falls, Idaho, and Soil Scientist, Division of Soil Management and Irrigation, U. S. Department of Agriculture, Logan, Utah, respectively.

[3] Numbers in parentheses refer to literature cited.

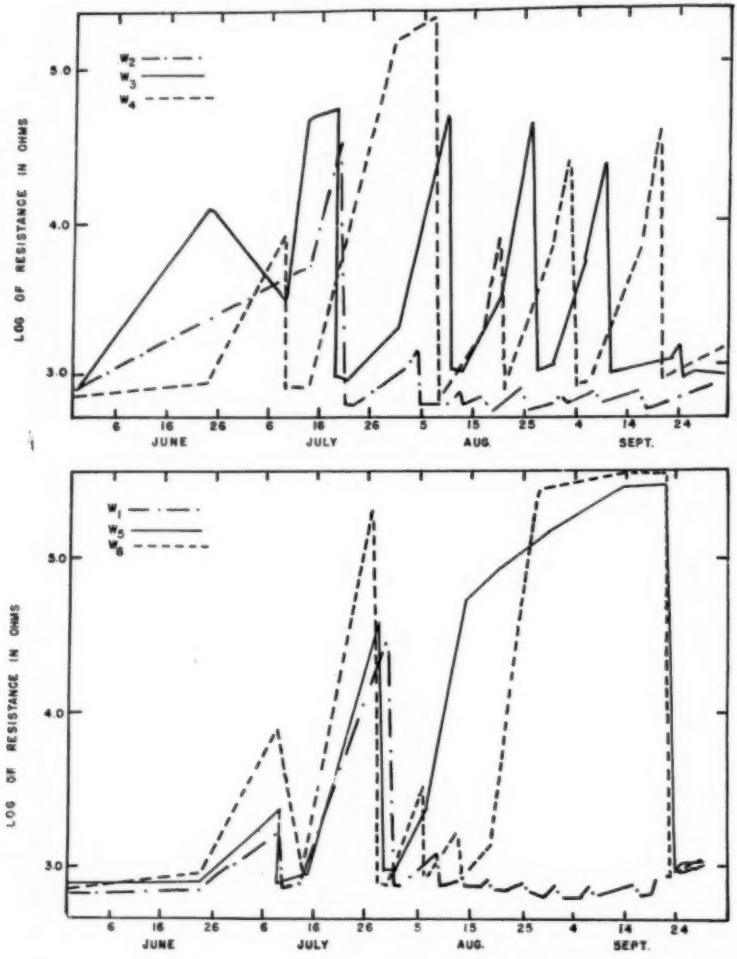
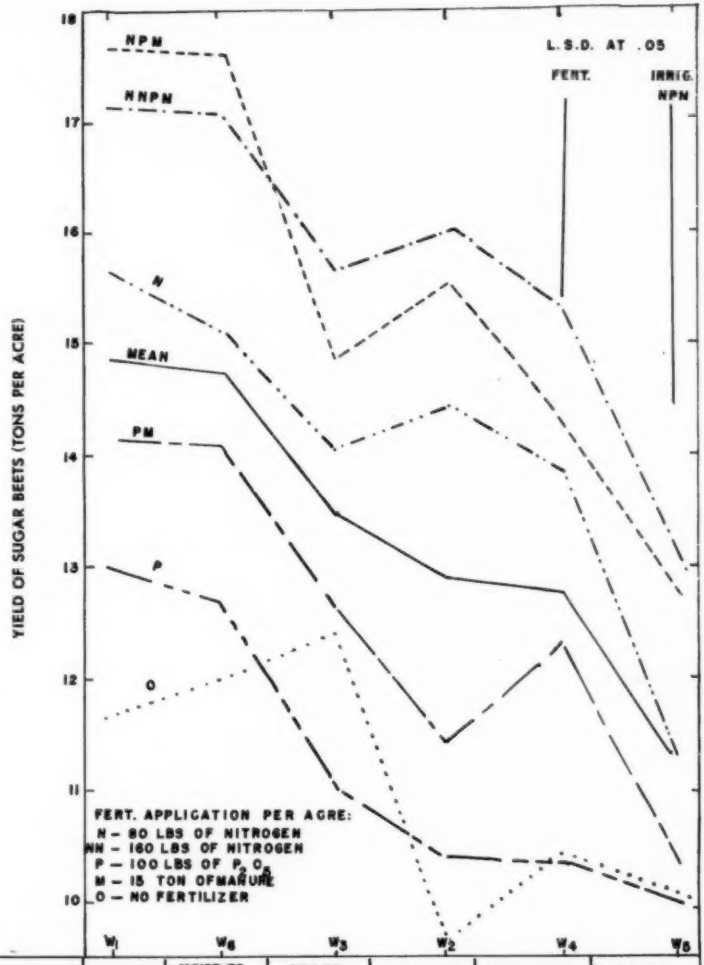


Figure 1. Seasonal soil moisture condition as indicated by resistance blocks.

graphically in Figure 1 that soil moisture conditions for treatments W_1 and W_2 were similar throughout the season. Likewise treatments W_3 and W_4 present a similar seasonal pattern. Treatments W_5 and W_6 were comparable except that the soil became relatively dry on treatment W_5 by August 15, while a similar condition was not reached on W_6 until August 25.



SOIL MOISTURE	MOIST ALL SEASON	MOIST TO AUG. 14 DRY	DRY TO JULY 20 MOD. MOIST	MOIST ALL SEASON	MOD. MOIST ALL SEASON	MOIST TO JULY 29 DRY
IRRIG.	10 SPRINKLE	2 SPRINKLE 3 FURROW	5 FURROW	9 FURROW	2 SPRINKLE 4 FURROW	2 SPRINKLE 1 FURROW
WATER (INCHES)	21.2	12.8	19.4	32.8	21.1	7.0

Figure 2. Yield in tons of sugar beets per acre for each of the irrigation and fertilizer treatments and for the mean of the fertilizer treatments.

Experimental Results

Yield of Sugar Beets and Method of Irrigation

The yield data for six irrigation treatments and six soil fertility treatments studied in this experiment are presented graphically in Figure 2.

It will be observed that plots kept moist all season by sprinkler irrigation (W_1) and those kept moist only until August 14 (W_0) gave the highest yields of beets. When an attempt was made to keep the soil relatively moist all season by furrow irrigation (W_2) yields were adversely affected, especially where commercial nitrogen fertilizer was not applied.

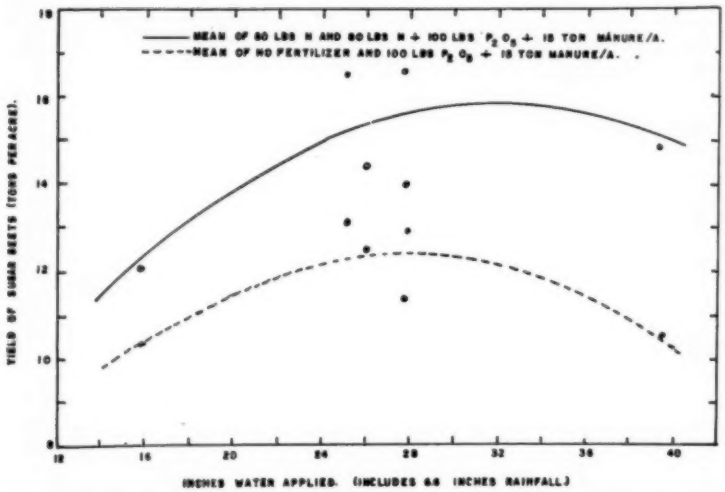

MEAN OF 80 LBS N AND 80 LBS N + 100 LBS P_2O_5 + 15 TON MANURE/A.
MEAN OF NO FERTILIZER AND 100 LBS P_2O_5 + 15 TON MANURE/A.
YIELD OF SUGAR BEETS (TONS PER ACRE).
INCHES WATER APPLIED. (INCLUDES 6.6 INCHES RAINFALL)

Figure 3. The relationship between the yield of sugar beets and the total depth of water applied (inches) for the mean yield of fertilizer treatments $N_1P_0M_0$ and $N_1P_1M_1$, and the mean yield of fertilizer treatments $N_0P_0M_0$ and $N_0P_1M_1$.

The irrigation water required to keep the soil moist all season by sprinkling was approximately 21 inches while more than 30 inches was required by furrow irrigation. It would appear that 9 inches of excess irrigation water were lost by deep percolation under treatment W_2. That available nitrogen was also lost with this leaching effect is indicated by the fact that beet petioles from W_2 plots were lower in nitrate-nitrogen than were petioles from any of the other irrigation plots.

It will be noted that nearly as much irrigation water was required for moderately dry plots ($W_3$and W_4) as for the moist plot (W_1), and yet yields tend to be consistently lower on the drier plots. It is probable that some water was lost by deep percolation from treatments W_3 and W_4, although insufficient evidence is available on this point.

Irrigation and Nitrogen Fertilization

The data in Figure 2 show that nitrogen fertilizer modifies the effect of irrigation treatment. This is particularly noticeable in a comparison of irrigation treatments W_2, W_3 and W_4. It will be observed that the three fertilizers resulting in yields above the mean contain nitrogen and that irrigation treatment W_2 tends to give a higher yield than treatments W_3 and W_4. On the other hand, the three fertilizers giving yields below the mean do not contain commercial nitrogen. When soils are low in available nitrogen or when fertilizers do not contain commercial nitrogen, irrigation

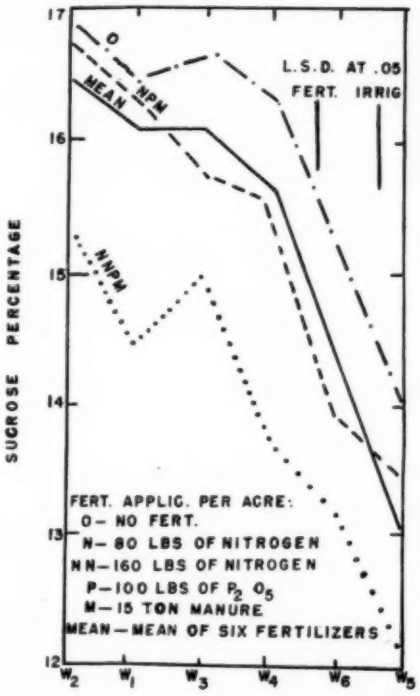


Figure 4. Sucrose percentage of sugar beets as influenced by irrigation practice.

treatment W_2 tends to result in yields lower than those obtained in treatments W_3 and W_4. This interaction between yields of beets from plots receiving no nitrogen vs. nitrogen x irrigation treatments is highly significant.

An analysis of the data on yield and total depth of water applied indicates a significant interaction of irrigation x nitrogen levels in the soil. This interaction is a linear effect which is highly significant and is shown by the relationship of the two curves in Figure 3. As the quantity of water and soil nitrogen are increased simultaneously, the distance between these two lines continue to increase. This tendency would undoubtedly change as aeration becomes limiting.

Time of Irrigation

Previous observations have indicated that young sugar beet plants are adversely affected by dry soil conditions. Furthermore, data were obtained during 1946 and 1947 which led to the assumption that sugar beets were not seriously affected by drought during the latter half of their growing period. Apparently this assumption was not well founded. The soil moisture condition under treatments W_5 and W_6 are similar except that plots with treatment W_5 became relatively dry ten days earlier than those with treatment W_6 (see Figure 1). This apparently critical period resulted in a yield differential on moderately fertile soil of nearly 5 tons of beets.

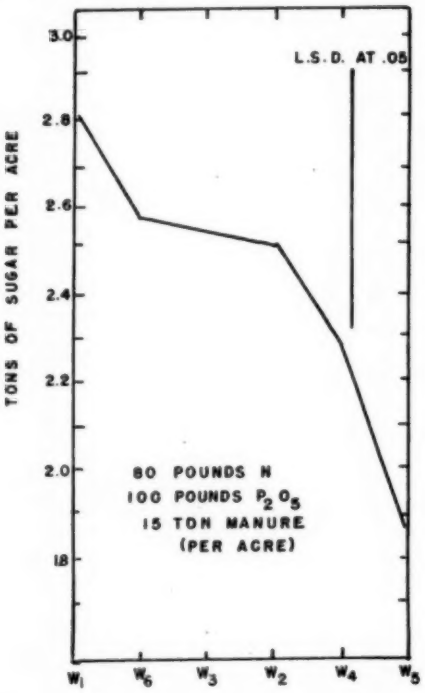


Figure 5. Yield of sugar as influenced by irrigation.

Irrigation Practice Affects Sucrose Percentage and Yield of Sugar

The data in Figure 4 clearly indicate that sugar beet soils should not remain dry for extended periods immediately preceding harvest. Late fall growth (stimulated by fall rains and an abundance of nitrate-nitrogen accumulated in the soil during the dry period, or nitrogen rapidly made available immediately after soil moistening), markedly depressed sucrose percentage. It will be observed that the sucrose percentage of beets grown under conditions of treatment W_5 was depressed more severely than those under conditions of treatment W_6, while beets from both of these plots were affected to a greater extent than those given treatments W_3 and W_4. Beets

grown in plots which were kept moist all season (W_1 and W_2) tended to mature early and were generally higher in sucrose than those from plots which were dry for an extended period. Beets grown under treatment W_2 tended to be higher in sucrose than those under treatment W_1. This observation supports the previous conclusion that possibly some of the available soil nirogen was lost by deep percolation under treatment W_2.

The data in Figure 5 show that irrigation treatment W_1, which encouraged rapid continuous growth of beets with good yields and high sucrose percentage, gave highest yields of sugar. Although treatment W_6 encouraged high yields the extended dry period late in the season was detrimental to sucrose percentage. Treatment W_2 encouraged high sucrose but low yield of beets and hence only moderate gross sugar production. Irrigation treament W_5 depressed sucrose percentage and yield and therefore gave a low yield of gross sugar.

Discussion

It is evident from the data presented that there is a close relationship between irrigation practice and available soil nitrogen. The ideal irrigation practice for sugar beets, as indeed for all crops on normal non-saline soils, should result in a moist soil profile with the minimum of water. This is important, not only for the efficient use of water, but also for the conservation of soil nitrogen.

The fact that yields of sugar were greatest under sprinkler irrigation does not mean that this is the most practical method of irrigation. However, it does suggest that proper control of irrigation water is an important factor in sugar beet production. The idea held by many farmers and expressed by some field men that sprinkler irrigation will result in short, stubby, branching beet roots is not in agreement with facts obtained in this experiment.

It is difficult if not impossible to keep a sugar beet field moist by furrow irrigation without losing substantial quantities of water by deep percolation. It appears as though loss of irrigation water by deep percolation is accompanied by concomitant losses of available soil nitrogen. Excess irrigation water applied to soils already low in available soil nitrogen may bring a substantial depression in sugar beet yields.

Sugar beets appear to be sensitive to extremely dry soil conditions until about the middle of August in the Great Basin area. Evidence is too meager to make precise statements about the critical physiological periods of sugar beet growth as influenced by irrigation. However, since extended periods of drought preceding harvest result in substantial reductions in sucrose percentage it appears advisable to continue with moderate irrigations until shortly before harvest.

Final justification for a given field practice is not to be found in the yield of beets nor the sucrose percentage of beets, but rather in the product of these.

When sufficient evidence is available on the relationship between irrigation practice and available soil nitrogen it would appear that a given level

of soil fertility will call for a rather definite irrigation practice in order to insure maximum sugar production.

Summary

1. Irrigation practice for sugar beets should be modified, not only to suit the texture of the soil, but the available supply of nitrogen.

2. The lower the available nitrogen supply of a soil the more seriously will excess irrigation water depress yields. The more abundant the available nitrogen supply in a soil the smaller the reduction in yield will be from excessive water application.

3. Experiments designed to study the effects of irrigation practice on yield and quality of sugar beets should not neglect the soil fertility status. Likewise, experiments designed to study soil fertility status should account for irrigation practice.

4. It is difficult to adequately furrow-irrigate a crop of sugar beets without losing some water and nitrogen by deep percolation. An attempt should be made to keep this loss to a minimum, especially on soils relatively low in available soil nitrogen.

5. Too little and too much irrigation water in relation to the available soil nitrogen are twin evils in sugar production.

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Fertilizer Studies with Sugar Beets in South Central Montana[1]

W. E. Larson[2]

The average sugar beet yield in Yellowstone and Big Horn counties in Montana over a period of years has been about 12 to 13 tons per acre. In contrast, some of the better farmers have averaged nearly 20 tons per acre and yields of more than 30 tons per acre have been obtained. It is well known that high sugar beet yields are the result of a combination of many management factors. It was thought, however, that soil fertility may be one of the most important factors in determining sugar beet yields in these areas. Accordingly, this study was begun.

Table 1.—Fertilizer and Manure Treatments Used in the 1950 and 1951 Experiments.

Treatment No.	Treatment per acre			
	Lbs. N	Lbs. P_2O_5[1]	Lbs. K_2O	Tons Manure
1	0	0	0	0
2	80	0	0	0
3	0	80	0	0
4	80	80	0	0
5	40	80	0	0
6	160	80	0	0
7	80	160	80	0
8	80	80	0	0
9	80	80	0	15
10	0	80	0	15
11	0	0	0	15

[1] In 1950 treatments, 3, 4, 5, 6 and 8 received 160 pounds P_2O_5 and treatment 7 received 80 pounds P_2O_5.

This report is concerned with (1) the effect of nitrogen, phosphorus, potassium and manure upon the yield and sugar content of sugar beets, and (2) the relation of the response to the soil chemical properties.

Experimental Methods

Thirteen fertilizer and manure experiments were conducted cooperatively with farmers on the Huntley Reclamation Project and in the vicinity of Hardin, Montana, during 1950 and 1951.

The fertilizer and manure treatments are given in Table 1. The eight fertilizer treatments occurred at all thirteen locations, whereas the manure treatments were included at two locations. The treaments include tests for N, P, K, manure, along with N x P interaction, and manure x fertilizer interaction. Ammonium nitrate, double superphosphate (43 percent) and 60 percent muriate of potash were used as fertilizer sources. All of the P, K and 10 pounds per acre of N were banded 3 inches to the side and 3 to 4 inches below the surface or 3 to 4 inches directly below the seed at planting time in the eight 1950 experiments. The remaining N was side-

[1] Joint contribution from the Bureau of Plant Industry, Soils and Agricultural Engineering, U.S.D.A., and the Montana Agricultural Experiment Station. The work was supported in part by grants from the Great Western Sugar Company and the Holly Sugar Corporation. Paper No. 257, Journal Series, Montana State College, Agricultural Experiment Station.

[2] Agent (Soil Scientist), Division of Soil Management and Irrigation, and Research Associate in Soils, Montana Agricultural Experiment Station. The author wishes to express his appreciation to Porter Pederson, Agricultural Aid (Cooperative USDA), and the staff of the Huntley Branch Station for their assistance and the facilities which they made available.

Table 2.—Chemical Properties of the Soils from 13 Fertilizer Experiments.

Soil No.	Soil Type	Organic Matter %	Total N %	Nitrifiable N PPM	PH	Exchangeable K M.E/100g.	Exchangeable Na M.E/100g.	Exchange Capacity M.E/100g.	Equivalent Conductivity KX10⁹	CO_2 Sol. P PPM
MO 1	Laurel clay loam	2.18	0.14	27.4	7.4	1.79	0.81	22.9	0.98	0.7
MO 2	Havre fine sandy loam	1.73	0.09	35.4	7.6	1.18	0.70	13.9	1.24	8.3
MO 3	Harlem silt loam	2.05	0.12	41.1	7.4	1.37	0.56	23.0	1.08	3.2
MO 4	Laurel clay loam	2.16	0.13	37.7	7.5	1.04	0.54	28.3	1.78	16.6
MO 5	Manvel silty clay loam	1.79	0.12	32.2	7.6	1.45	1.63	31.7	1.38	1.0
MO 6	Billings silty clay	2.36	0.16	35.2	7.6	1.66	2.33	33.2	2.41	0.8
MO 7	Manvel clay loam	1.60	0.12	31.6	7.7	1.03	1.61	23.6	1.72	1.8
MO 8	Manvel clay loam	1.61	0.11	30.6	7.7	0.82	0.90	21.0	1.28	1.2
MO 9	Havre fine sandy loam	1.92	0.10	30.3	7.8	1.33	0.21	14.3	0.80	7.5
MO10	Laurel clay loam	2.10	0.10	41.2	7.8	1.12	1.56	28.1	0.80	0.5
MO11	Havre fine sandy loam	1.79	0.10	46.4	7.7	0.91	1.62	20.4	3.09	0.5
MO12	Billings clay	2.66	0.16	49.6	7.7	1.55	1.33	30.2	1.40	0.4
MO13	Manvel silty clay loam	1.78	0.11	40.4	7.8	1.53	0.98	20.5	1.01	2.4

Table 3.—Effect of Nitrogen, Phosphorus and Potassium on the Yield of Sugar Beets in 13 Experiments in South Central Montana during 1950 and 1951.

Fertilizer Treatment	1950 Experiments								1951 Experiments				
	MO1	MO2	MO3	MO4	MO5	MO6	MO7	MO8	MO9	MO10	MO11	MO12	MO13
1	10.0	14.6	14.4	11.0	17.5	16.6	14.6	13.1	19.6	12.6	14.5	13.2	11.9
2	10.0	16.5	16.9	14.1	18.1	17.4	16.5	13.8	21.4	16.4	15.0	16.1	13.5
3	15.1	14.7	14.3	12.2	16.2	17.4	14.9	13.1	19.6	14.5	15.6	13.0	10.7
4	14.7	15.6	16.7	15.3	19.2	18.0	16.8	14.3	22.3	17.8	16.5	15.1	13.9
5	16.4	15.9	16.2	13.5	20.6	18.0	16.6	14.3	22.4	15.6	16.7	15.7	13.6
6	15.8	16.0	17.7	14.8	18.3	17.2	17.1	14.2	22.5	16.9	15.8	17.6	14.0
7	15.4	17.7	17.1	14.5	18.2	17.8	16.5	14.1	22.2	17.2	17.8	15.6	13.2
8	15.8	18.1	17.0	14.8	19.8	18.7	16.9	14.3	22.2	17.1	17.9	16.2	14.4
LSD (.05)	2.1	1.3	2.1	1.7	2.1	1.2	1.5	0.8	2.2	2.0	2.2	2.4	1.3
LSD (.01)	2.8	1.8	....	2.3	2.8	....	....	1.0	....	2.8	3.0	3.3	1.8

dressed about June 15. All the fertilizer was applied 3 inches to the side and 3 to 4 inches below the surface at planting time in the 1951 experiments. Manure was broadcast in the spring prior to plowing. All plots were four rows wide and either 50 or 60 feet long with the two center rows harvested for yield. Either four or five replications were used. Subsamples taken from measured distances in the yield rows were used for sugar analysis to avoid bias in selection.

Gypsum resistance blocks were used as guides in timeliness of irrigation. Plant populations were good and were never below 76 percent. Eight experiments had row widths of 22 inches; two, 26 inches, and one, 24 inches.

Statistical analysis of the combined experiments was conducted generally according to Cockran and Cox (1)[3]. The problem of analyzing combined experiments has been recently discussed by Salmon (3). Attempts were made to group the data as much as possible into homogeneous treatment effects. For example, in the thirteen experiments only one produced a phosphorus yield response, whereas the other twelve gave significant or near significant nitrogen yield increases. They were thus grouped accordingly and an F test showed the groups were not homogeneous and should not be combined. A K x location interaction was calculated and found not significant. In most cases an unweighted pooled error from all experiments was used for F tests and least significant difference calculations. However, where appropriate, a treatment x location interaction was used.

Soil samples were obtained from the 0-7 inch depth from each location. Organic matter, total N, exchange capacity, exchangeable Na, exchangeable K and conductivity were determined by standard methods. Nitrifiable N as determined here is the amount of nitrates produced when the soils were incubated at 30 percent moisture at 25° C. for three weeks. CO_2 soluble phosphorus is that amount soluble when a constant stream of CO_2 was bubbled through 10 grams of soil in 50 ml. of water for 30 minutes.

Percent sugar in the sugar beet roots was determined by a standard method.[4]

Description of Experiment Sites

The soils in the area studied were developed from stratified sandy, silty and clayey alluvium on the lower stream terraces and fan terraces adjacent to the Yellowstone and Big Horn rivers. In general, the soils do not have well defined genetic horizons.

Past cropping practices were dominated by small grain and sugar beets with only two fields having grown alfalfa within the last 6 years.

The soil types at the experiment sites and chemical properties of the soils are presented in Table 2. Exchangeable Na and conductivity measurements indicate that neither Na nor soluble salts are seriously limiting sugar beet growth on the soils. Soil pH's varied from 7.4 to 7.8 and all soils were slightly calcareous as evidenced by effervescence with acid. Organic matter and total N range from 2.18 to 1.60 and 0.16 to 0.09 percent, respectively.

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[3] Numbers in parentheses refer to literature cited.
[4] Sugar and tare determinations were made by the Holly Sugar Corporation and the Great Western Sugar Company.

Results and Discussion

The effects of N, P, K, manure fertilization and their interactions are discussed individually below. Results for the individual experiments are given in Table 3. Results for the manure experiments are presented in Table 4. The mean effects of N, P, K, and manure on yields of sugar beet roots and the effects of N on sugar percentage and total sugar are presented in Table 5.

Nitrogen

The mean yield increase for 40, 80 and 160 pounds of N per acre was 1.95, 2.10 and 2.09 tons per acre, respectively. Twelve experiments were included in this mean. The maximum and minimum yield increase on the individual experiments was 4.4 and 0.6 tons per acre, respectively. Eighty pounds of nitrogen produced more sugar beet roots than did 40 on only two of the experiments. In a few cases 160 pounds of N out-yielded 40 pounds but in no case produced more than 80 pounds of applied N.

Table 4.—Effect of Fertilizer and Manure on the Yield of Sugar Beets in 2 Experiments in South Central Montana during 1951.

Treatment per acre				
N lbs.	P_2O_5 lbs.	Manure Tons	MO9	MO13
0	0	0	19.6	11.9
0	80	0	19.6	10.7
80	80	0	22.3	13.9
0	0	15	20.2	12.5
0	80	15	20.6	11.8
80	80	15	22.8	14.6
	LSD (.05)		2.2	1.3
	LSD (.01)		—	1.8

Applied N fertilizer reduced the percent sugar on all 13 individual experiments and the mean of the combined experiments. Forty, 80 and 160 pounds of N reduced the mean sugar percent by 0.17, 0.52 and 1.19, respectively. Each successive larger rate produced highly significant mean reductions. The percent sugar for the individual experiments is not given because of the uniform treatment x location effects and because of lack of space.

The mean total sugar increase per acre was 616, 563 and 335 pounds per acre for 40, 80 and 160 pounds of applied N, respectively. Rates of 80 or 160 pounds of N per acre produced significantly more total sugar than did 40 pounds on three of the individual experiments, reduced total sugar on six of the experiments and had no effect on sugar production on three experiments.

On the basis of these experiments, it appears that 40 pounds of N will give a profitable yield increase on most fields in the area. Eighty pounds will probably be profitable on some fields. It is doubtful whether 160 pounds will be a desirable rate on any field in the area with normal past cropping practices.

The efficiency of the N is illustrated by calculating the pounds of sugar produced per pound of N applied. The mean values for 40, 80 and 160

pounds of applied N from 12 locations are 15.4, 7.0 and 2.0 pounds per acre. The maximum amount of sugar produced per pound of N applied on any one experiment was 32.0.

It was thought that the reduction in percent sugar on the 1950 experiments was accentuated by late application of N. In addition, a period followed when the soil was too dry for effective N uptake. Therefore, in 1951 all nitrogen was applied at planting time. Because of differences in location, no definite conclusions can be drawn. However, reductions in sugar percent due to N were almost identical in 1951 and in 1950.

Neither total N, organic matter nor nitrifiable N gave significant correlations with yield response to N fertilizer.

Preliminary data has indicated that the poor physical condition of the soil together with excessive amounts of irrigation water has resulted in poor

Table 5.—The Mean Effect of Nitrogen on Yield, Sugar Percent and Total Sugar and the Effect of Phosphorus, Potassium and Manure on Yield of Sugar Beets in 13 Experiments during 1950 and 1951.

Item Tested	Total No. of Loc. Tested	No. of Loc. Grouped for Comparison	Check[1]	Difference from Check Due to Treatment Indicated per acre			Least Significant Difference 5%	Least Significant Difference 1%
				Nitrogen (N) Lbs.				
				40	80	160		
Yield, T/A.	13	12	14.67	1.95	2.10	2.09	0.82	1.08
Sugar, %	13	13	17.03	—0.17	—0.52	—1.19	0.14	0.18
Sugar, lbs/A	13	12	5,005	616	563	335	222	294
				Phosphorus (P_2O_5) Lbs.				
					80	160		
Yield, T/A.	13	1	10.04	.....	5.40	4.66	1.71	2.25
				Potassium (K_2O) Lbs.				
					80			
Yield, T/A.	3	3	15.49	.....	0.76	.....	0.90	0.68
				Manure Tons				
					15			
Yield, T/A.	13	13	16.63	.....	0.57	.....	0.52	.....

[1] Plots having nitrogen variables received a basic application of 80 or 160 pounds P_2O_5 per acre. Phosphorus variables received a Basic Application of 80 pounds N per acre. Potassium variables received 80 pounds N and 80 or 160 pounds P_2O_5 per acre. The value for manure is calculated from plots which received manure alone, manure and phosphorus, and manure, nitrogen and phosphorus with appropriate comparisons.

soil aeration on many fields. This factor may be important in limiting microbial action and in N mineralizing. If so, differential aeration would explain the poor relation between N yield response and nitrifiable N. These results are in general agreement with Nelson et al (2) although the yield increases reported here are somewhat larger and the reduction in percent sugar is greater.

Phosphorus

Phosphorus applications produced more roots and total sugar on only one of the thirteen experiments. Eighty and 160 pounds were equally effective and P had no effect on sugar percent.

Past management records revealed that P had been applied to the experimental sites approximately 50 percent of the time during the previous four seasons. The residual effect of this applied P probably accounts for the lack of P response on many of the fields.

The response data for P is too limited for correlation with CO_2 soluble phosphorus.

Potassium

Potassium produced a yield increase of more than 0.5 ton on six of the 13 fields although only one field showed significance. When combined the mean yield increase was 0.57 tons per acre for the 13 fields. Percent sugar was not affected.

Potassium has not previously been recognized as deficient in the area studied. Exchangeable K values of the soil from the experiments ranged from 0.82 to 1.79 M.e. per 100 grams of soil or from 640 to 1,396 pounds per acre six inches. There was no relation between exchangeable K and K response in the field. The amounts of exchangeable K are much in excess of those recognized as critically low in other areas. Several factors are unfavorable for optimum K uptake and were thought to have been present in the experiments. These include a crop with a large K requirement, free Ca CO_3 in the soil, poor soil aeration and a large amount of nitrates in the soil.

Manure

Manure produced no significant yield increases on the two individual experiments. A mean increase of 0.76 tons per acre for the two experiments approaches significance at the 5 percent level.

Interactions

There was no N x P interaction on any single experiment or to the mean of all experiments. This is probably because the deficiency of one element was at no time serious enough to limit the efficiency of the other.

No interaction was present between manure and P or N plus P. This indicates that on the fields studied much of the manures' effectiveness in increasing yields can be attributed to a more favorable soil physical condition.

Summary

Thirteen sugar beet fertilizer studies were conducted on the Huntley Reclamation Project and in the vicinity of Hardin in south central Montana during the growing seasons of 1950 and 1951. An attempt was made to keep other soil and crop management factors near optimum. The results can be summarized thus:

1. Nitrogen fertilizer increased the yield of sugar beet roots on 12 of the 13 locations, decreased the sugar percentage on all locations and increased the total sugar production on 10 locations. The mean yield increase for 40, 80 and 160 pounds of N per acre was 1.95, 2.10 and 2.09 tons per acres, respectively. Sugar percentage was decreased by 0.16, 0.52 and 1.19 by 40, 80 and 160 pounds of nitrogen, respectively. Forty, 80 and 160 pounds

of N increased total sugar production by 616, 563 and 335 pounds per acre, respectively.

2. Eighty and 160 pounds of P_2O_5 were equally effective in increasing yields on one of the thirteen locations, whereas the remaining 12 were not found deficient. Phosphorus had no effect on sugar percentage.

3. A nitrogen phosphorus interaction was not evident on any location.

4. Potassium produced a significant yield increase on one individual experiment. The mean yield increase for all experiments was 0.57 tons per acre and was significant.

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The Effect of Reduced Emergence Upon the Proportion of Singles and Doubles in Field Stands of Sugar Beets

L. D. Leach and Roy Bainer[1]

The degree of singleness that is most desirable for the production of optimum field stands is one of the major considerations in the processing of sugar beet seed.

Between 1942 and 1946, when segmented seed was widely used, several operators believed that the problem of reducing the labor required for thinning could best be solved by producing as complete singleness of seed as was possible by mechanical processing. When such seed was planted at low seeding rates where emergence conditions were poor, light and irregular stands often resulted.

Table 1.—Relation of Field Germination to Singleness with Whole, Segmented and Decorticated Beet Seed.

Type of Seed	Size 64th in.	Germination Percent	Seedlings per Viable Unit	Field[1] Germ. Percent	Inch. with singles Percent
Whole	10-12	96.0	1.84	70.4	45.7
Whole	10-12	96.0	1.84	44.5	57.5
Whole	10-12	96.0	1.84	30.1	72.7
Segmented	8-10	92.6	1.38	53.9	70.1
Segmented	8-10	92.6	1.38	30.5	82.8
Decorticated	8-10	95.7	1.89	64.4	48.6
Decorticated	8-10	95.7	1.89	55.5	50.0
Decorticated	7- 9	92.0	1.59	45.2	70.2

[1] Field germination refers to the emergence of seedlings in the field as a percentage of the total seedlings per 100 seed units as shown by laboratory or greenhouse germination trials.

With the introduction of decortication (1)[2], seed with a higher degree of doubleness was produced and in most cases a more satisfactory stand resulted, although the labor requirement for thinning was somewhat greater than with seed characterized by extreme singleness. Early trials in the precision distribution of graded whole seed showed that the percentage of singles occurring in field plantings was often higher than the percentage of singles shown in laboratory germination. A critical examination of field stands showed that the percentage of singles in field stands was inversely related to the percent of potential emergence. Examples of this relation are shown in Table 1, with graded whole seed, segmented and decorticated seed.

With each seed type there is a noticeable tendency to produce a higher percentage of singles in those trials where the field emergence is the lowest. Seed with a high percent of doubles may under conditions of low emergence produce as high as 70 percent singles in field emergence.

The relative number of singles, doubles and multiples observed in laboratory germination and in field emergence is shown graphically in Figure 1 for two machine plantings, using both segmented and decorticated seed, and for a hand planting using high gravity segmented seed.

[1] Plant Pathologist and Agricultural Engineer, respectively, University of California, Davis, California.

[2] Numbers in parentheses refer to literature cited.

When adjusted to equal seeding rates the data for the Brown planting show that approximately the same number of singles per 100 inches was produced by each of the seeds. More total seedlings, more inches with beets and more doubles and multiples were produced by the decorticated seed, while the segmented seed showed the highest percentage of singles.

A comparison of the laboratory germination and field emergence of the seed lots shows that the percentage of potential emergence for decorticated seed was somewhat higher than for segmented seed and that, per 100 seed units, the decorticated seed produced more singles than segmented as well as more inches with beets and total seedlings. Because of fewer doubles and

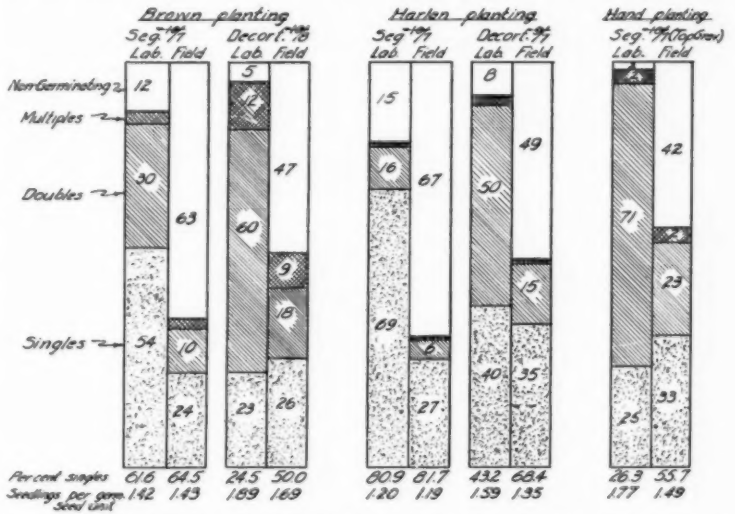

Figure 1.—Comparison of singles, doubles and multiples in laboratory germination and field emergence with three plantings.

multiples, the segmented seed shows a higher percentage of single beets. While the segmented seed showed only a small difference in percent of singles between laboratory germination and field emergence, the decorticated seed showed twice the percent of singles in the field than was indicated by the laboratory germination.

In the Harlan planting the results were similar to the Brown planting in that the number of singles per 100 inches is about the same for the two types of seed, while the decorticated seed produced more inches with beets and more total seedlings but a lower percentage of singles.

When compared on the basis of emergence per 100 seed units, the decorticated seed again produced a greater number but a lower percentage of singles than segmented seed. Decorticated seed, however, with only 43 percent singles in the laboratory germination, produced 69 percent of singles in the field. Segmented seed with 81 percent singles in the laboratory germination in the same field planting produced 82 percent singles.

The results from these two fields and from a number of other trials by

different investigators show clearly that field emergence may show a different proportion of single, double and multiple beets than laboratory germination. It is evident that seed lots containing a high percentage of singles show about the same proportion of singles in field emergence, whereas seed lots made up chiefly of doubles show a decided shift toward singleness in field emergence.

To completely evaluate this relation by experimentation would require a very large number of trials using seed lots with different degrees of multi-

Table 2.—Mathematical Expectation, Per 100, that Viable Double-germ Seed Balls Will Produce Single or Double Seedlings with Different Levels of Emergence. Assuming Independent Germination.

Doubles (2.0)

Emergence		0	1	2	Germ. units	
	p_s	p_0	p_1	p_2	p_3	Seedlings per seed unit
100 x	—	$(1-p_s)^2$	$2p_s(1-p_s)$	$(p_s)^2$	$1-p_0$	
	100	0	0	100	100	2.00
	90	1	18	81	99	1.82
	80	4	32	64	96	1.67
	70	9	42	49	91	1.54
	60	16	48	36	84	1.43
	50	25	50	25	75	1.33
	40	36	48	16	64	1.25
	30	49	42	9	51	1.18
	20	64	32	4	36	1.11
	10	81	18	1	19	1.05

Symbols

p_s—probability of seedling emergence (percent of potential seedling emergence).
p_0—probability of non-germinating seed unit.
p_1—probability of single seedling.
p_2—probability of doubles.
p_3—probability of seed units producing 1 or more seedlings.

plicity, each germination at different levels of emergence. Corrections would also have to be made for planter performance, seeding rate and for non-uniformity of the environment within the plots.

In the opinion of the authors a probable explanation for this phenomenon is the independence or near independence of the germination of individual seeds. In this case the probability of a seed germinating would be about the same whether it occurs in a single or a multiple seed unit. We have, therefore, calculated the results which would be expected with independent germination and then tested the theory by germination trials in a controlled environment and in field plantings.

If we assume independent germination of individual seeds and that environmental conditions within the plot are uniform, we can calculate the mathematical expectation that single, double or multiple seed units will produce blanks, singles, doubles or triples at different levels of field emergence (percentages of potential emergence). Examples of the application of this formula to double germ seed are presented in Table 2 and Figure 2. In the same way by trinomial expansion a table can be prepared for emergence from triple germ seed.

By applying the formula for probability, as shown in Table 2, we secure an approximation of non-germinating units, single, double or triple seedlings per 100 viable units at any level of emergence for single, double or

triple seed balls. It is evident that the multiplicity of emerging seedlings would be strikingly reduced as the percentage of potential seedling emergence is lowered. From these tables it is possible to compute the expectancy, at any level of emergence, from any seed lot for which the percentage of non-viable, single, double and multiple seed units is known. For example, Figure 3 shows the theoretical relation between the laboratory germination and the expectancy of field emergence at different levels of emergence for a seed lot with 1.5 seedlings per viable seed unit.

Emergence Under Controlled Conditions

This relation was next tested by planting four lots of 100-seed units each of whole and decorticated seed in compartmented trays so that the emergence from each seed unit could be followed. This planting was made in pasteurized soil in the greenhouse under ideal germinating conditions and

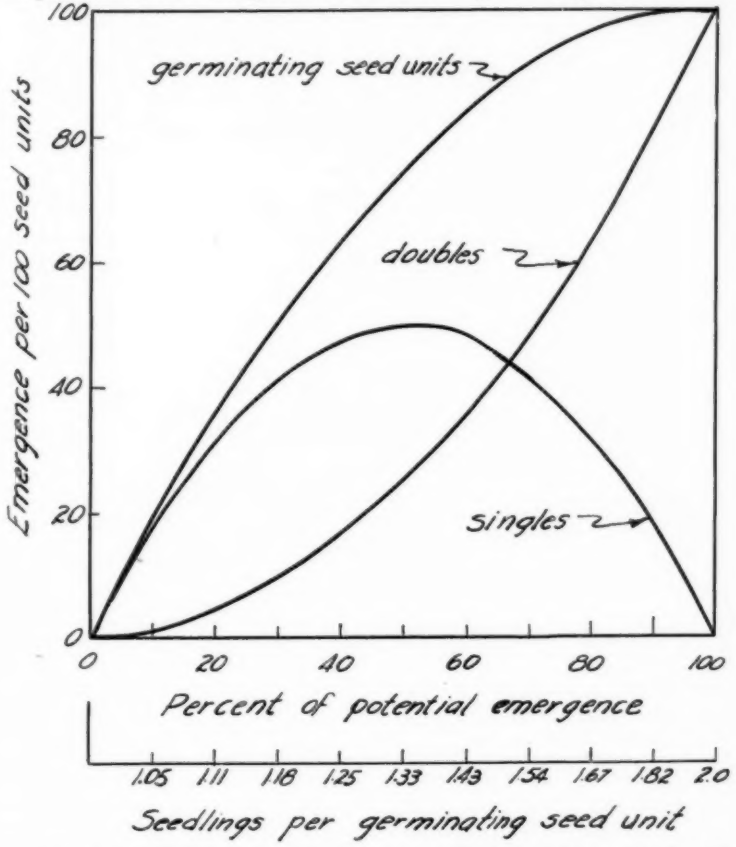

Figure 2.—Mathematical expectation per 100 that double seed balls will emerge as singles or doubles at different percents of potential emergence.

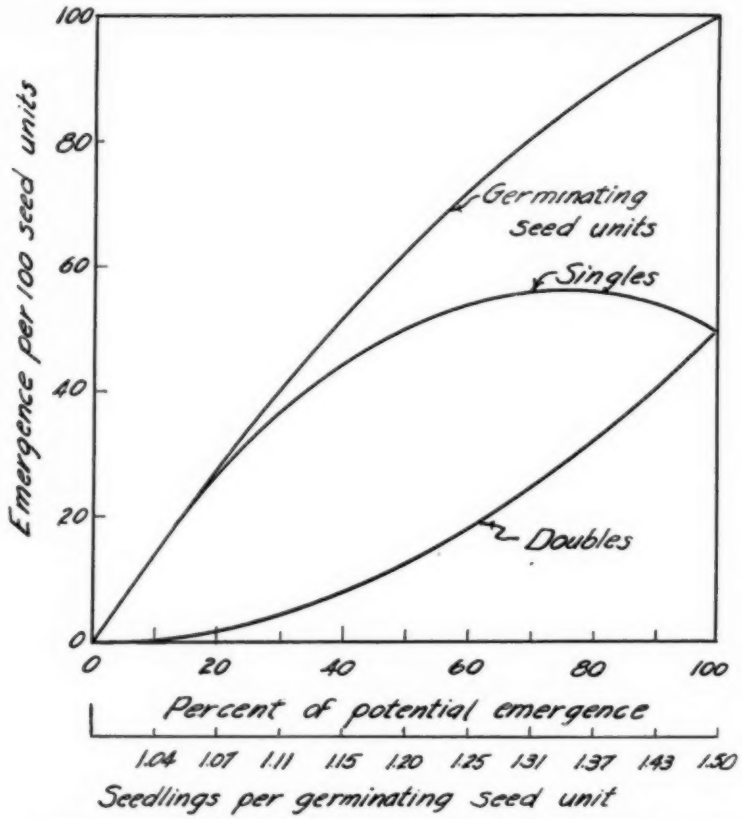

Figure 3.—Anticipated emergence of single and double seedlings at different levels of emergnce from seed units with a laboratory germination averaging 1.5 seedlings per viable seed unit.

observations were recorded at intervals of from 6 to 10 hours from the appearance of the first seedling until emergence was completed. As shown in Table 3 and Figure 4, in practically all cases the first seedlings emerged as singles and later in the germination period a second and sometimes a third or fourth seedling would appear from the same seed unit. As emergence progressed the number of seedlings per germination unit increased while the percent of singles decreased.

Under these ideal conditions the percent of singles at the various stages of emergence was nearly identical to the theoretical expectation and it can be concluded, therefore, that emergence of individual seedlings was practically independent.

It is evident also that if emergence of a seedling stand was interrupted by any adverse condition the percentage of single plants would be much

Table 3.—Emergence of Whole and Decorticated Beet Seed from Pasteurized Soil in a Controlled Environment.

	Hours after planting								
	130	136	142	148	156	166	174	192	336
Whole Seed									
Emergence—%	4	10	27	40	60	73	81	91	100
Singles—%	84	87	80	70	53	41	36	31	29
Seedl/germ. unit	1.16	1.13	1.22	1.34	1.51	1.65	1.73	1.83	1.90
Decorticated Seed									
Emergence—%	19	37	55	68	78	86	89	93	100
Singles—%									
Actual	92	85	71	59	56	52	49	46	41
Theoretical	91	83	72	64	57	52	49	46	40
Seedl/germ. unit	1.08	1.15	1.29	1.39	1.45	1.50	1.52	1.56	1.61

higher than if conditions remained uniformly favorable until emergence was completed.

Comparison of Field Data

All of the field data we have observed shows a higher percentage of singles in the field than shown by laboratory germination of the seed. In addition, Doxtator (3) reported tests showing that seed with 26 percent singles produced 56 percent singles in the field at 50 percent of potential emergence and in another trial a seed lot with only 8 percent singles produced 40 percent singles in the field at a 35 percent emergence level.

Using decorticated seed with from 1.55 to 1.65 seedlings per viable seed unit (about 40 percent singles), Tolman (5) found 65 percent singles in the field at 60 percent of potential emergence and 62 percent singles at an emergence level of 57 percent.

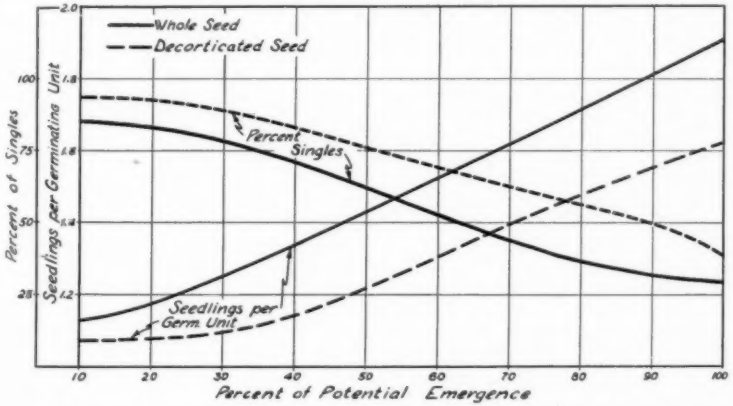

Figure 4.—Emergence of whole and decorticated beet seed in a controlled environment. The percent of singles decreased and the seedlings per germinating seed unit increased as the percentage of potential emergence approached 100.

From a large number of hand-and machine-planted trials Bush (2) concluded that, as an average for all seed lots studied, the percentage of singles in the field was about 12 percent higher than indicated by laboratory germination of the seed.

McBirney (4) analyzed data from a series of planter tests and found that as the percentage of field emergence increased by 1 percent the percentage of singles decreased by 0.51 percent. The slope of his curve was approximately the same as the theoretical expectation, but at the lower emergence levels the proportion of singles was about 15 percent lower than would be expected from independent emergence.

When the same test is applied to other field data it is found in nearly all cases that the proportion of singles is somewhat less than might be anticipated. Partial explanation for this discrepancy can be found in McBirney's data which show that with the same seed lots and the same planter the percent of singles in the field is influenced by the seeding rate. On an average the percentage of singles decreased by 0.6 percent for each increase of one in the number of seedlings per 100 inchs.

In the same way irregular distribution of the seed by the planter would decrease the apparent percentage of singles in the field, especially when measured by the 100-inch stick.

Still another source of variation is the non-uniformity of emergence conditions within the field. Emergence is usually reported as an average percentage for the plot or field, whereas within the area the level of emergence may vary from extremely low to a fairly high percentage of the potential. Such a variation will always tend to produce a lower percentage of singles than would be expected for the average level of emergence.

In general it appears, therefore, that field plantings show the same tendency toward increased singleness with lower levels of emergence as is shown by controlled plantings. Because of the effect of planter distribution, seeding rate and non-uniformity of emergence conditions, most field plantings show a lower percentage of singles than would be expected with completely independent emergence of seedlings.

The practical significance of this relation is the fact that under conditions of low emergence levels there is considerable advantage in leaving a fairly high percentage of doubles in the seed lot because they offer a greater probability of producing at least one seedling than do single germ units. Under extremely favorable conditions, however, the use of a seed lot with a higher percentage of singles offers the greatest possibilities for reducing the labor requirement for thinning.

The seed processor and the growers have the problem of balancing the degree of singleness in the seed lot and the rate of seeding to provide reasonably good field stands under the emergence conditions characteristic of each district.

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Possibilities of Improved Nitrogen Fertilization of Sugar Beets Through the Use of Leaf Analysis

W. R. Duckworth and F. J. Hills[1]

The problem of nitrogen fertilization in many areas is quite complicated (1) (4).[2] Responses to nitrogen may vary so markedly from field to field that it is impossible, even on the basis of field experiments, to arrive at general recommendations which will be satisfactory for a high percentage of fields. Furthermore, this variation in response to nitrogen not only occurs between adjacent fields, but can occur on the same field in different years. Table 1 gives the results of two trials conducted on the same field at closely associated locations and shows the variation in response to nitrogen on succeeding beet crops.

In some locations, such as the Woodland area of California, nitrogen appears to be one of the principal factors limiting yields and influencing sugar concentrations. During the crop years of 1949 and 1950 the Spreckels Sugar Company conducted a survey of sugar beet production problems in this area (2). This study utilized leaf analysis as a tool in evaluating the nutrient status of a large number of beet fields. The results indicated that in many fields yields were limited because of nitrogen deficiency and in others a high nitrogen level late in the season appeared to be one of the major reasons for lower sucrose concentration. The nitrogen status, as indicated by periodic petiole samples, of Field A in Figure 1 is typical of

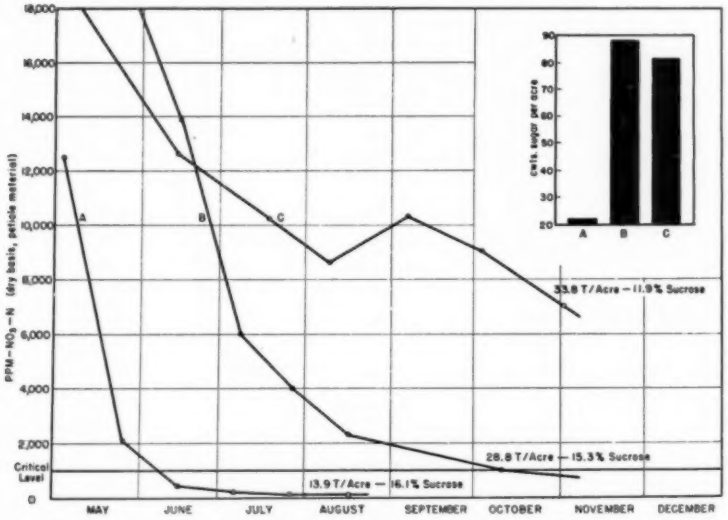

Figure 1.—The nitrogen status of three sugar beet fields as indicated by periodic petiole samplings.

[1] Field Superintendent, Spreckels Sugar Co., and Extension Agronomist, University of California, respectively.

[2] Numbers in parentheses refer to literature cited.

Table 1.—Effect of Nitrogen on Yield of Sugar Beets Grown on the Same Field in Different Years.

Lbs. N/Acre	Tons/Acre		% Sugar		Tons Sugar/Acre	
	1947	1950	1947	1950	1947	1950
0	25.0	14.6	17.5	15.6	4.38	2.26
80	27.9	20.0	16.9	15.6	4.71	3.13
160	28.0	21.6	16.1	15.0	4.52	3.24
240	27.8	20.9	15.5	13.9	4.47	2.90
LSD 19:1	2.1	1.3	0.5	0.3	NS	0.16

a field becoming deficient early in the season.

Figure 2 illustrates a correlation between the nitrogen status of beet fields and their sucrose concentration at harvest. The fact that such a correlation is obtained among fields differing greatly in management practices is evidence that nitrogen probably plays an important role in determining the sucrose concentrations of fields in such an area. In view of this situation, it would seem that there is much to be gained through more efficient fertilizer programs.

Through greenhouse and field experiments, the relationship of the nitrate content of beet petioles to the growth of sugar beet plants has been determined (3). A critical range has been established of 1,000 to 2,000 parts per million nitrate-nitrogen (dry basis). When the concentration of this nutrient in the petioles falls into this range, the growth of the plants will decrease. This critical level concept has been verified many times by field experiences. Figure 1 indicates how this technique can be used to evaluate how well a given crop was supplied with nitrogen. It is reasonable

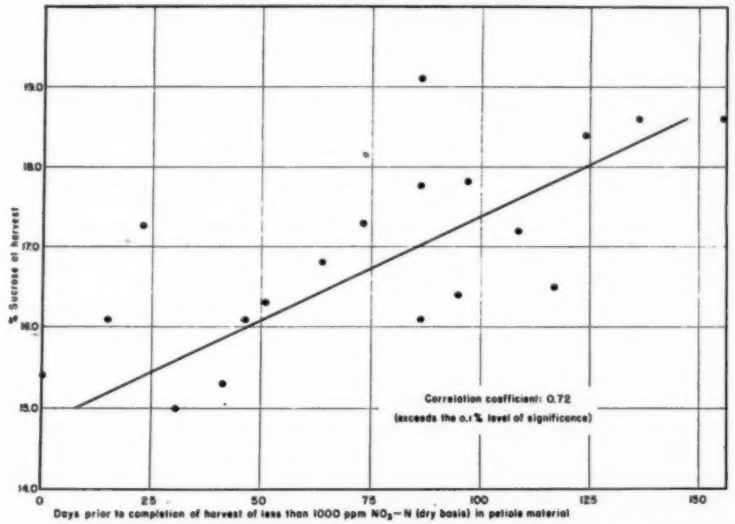

Figure 2.—The relationship of the duration of nitrogen deficiency, as indicated by petiole analysis, to sucrose concentration at harvest.

to conclude from such data, for fields which were observed closely throughout the growing season as these were, that a good deal of the difference in the performance of these crops was due to differences in the amount of nitrogen available. Obviously heavier nitrogen applications should be considered for Field A while it appears that Field C might have had a higher sucrose concentration if less nitrogen had been used. With respect to nitrogen, Field B appears to have been adequately fertilized.

Plant analysis might also be used effectively to indicate the need for supplemental nitrogen applications on growing crops. This would be particularly true with extreme fields. In cases where low fertility is suspected a basic nitogen application could well be supplemented profitably by another application should petiole samples indicate an approaching deficiency relatively early in the season. On fields of known high fertility, such as Field C in Figure 1, it might be well not to apply nitrogen but to watch the field closely through a petiole sampling program and fertilize only if the need arises.

In applying plant analysis to the problem of nitrogen fertilization of the current season's crop certain important considerations should be kept in mind. When the concentration of nitrate in the petioles falls below the critical level the growth rate of the plants will decrease. Plant analysis, however, can not tell how serious the deficiency is, how much fertilizer should be added to correct the deficiency or the magnitude of response to expect when the deficiency is corrected. These questions can only be answered by trial and through experience in a given area.

Experience gained to date indicates that investigations should be continued under a wide range of conditions so as to determine how leaf analysis can best be used to aid sugar beet fertilization.

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A Study of the Effects of Seven Systems of Cropping Upon Yields and Soil Structure[1]

L. S. Robertson[2]

A number of observations have been made in Michigan with regard to the effect of crop sequence upon yields and soil structure. During past years less progress has been made in increasing yields of sugar beets than of certain other farm crops. This is true despite the use of improved disease-resistant varieties, considerably more commercial fertilizer and more tile drainage. Sugar beets have commonly been grown on the better soils, those naturally high in organic matter. In many areas, little attempt has been made to improve or maintain the productive capacity of such soils by the growing of soil-building legumes. Consequently, organic matter has become depleted. Puddled soils and slow drainage have helped keep yields low.

As this deterioration of soil structure became evident, agronomists and others interested in the production of sugar beets in Michigan were asked for a solution to the problem. Would legumes and grasses improve the soils? How long should legumes be left in the rotation? Which legumes should be grown? What sequence of crops should be followed?

It was evident that these questions could not all be answered from existing experimental results, so it was decided that additional experiments should be started. Accordingly, the experiment involving seven systems of crop rotation was started in the spring of 1940. The effects of the different cropping systems on certain physical characteristics of the soil and the apparent relationship between those characteristics and crop yields are reported in this paper.

Description of Soil, Plots and Systems of Farming

The field experimental plots upon which these studies were made are located on the Lee Ferden farm near Chesaning, Michigan. The soil has been mapped as a Brookston sandy clay loam. Analyses showed that the surface soil contained 25 to 28 percent clay, 50 to 58 percent sand and 7.8 percent organic matter. The pH is 6.8, and the base exchange capacity is 13.45 m.e. per 100 gms. of soil, of which 8.95 m.e. are calcium, 0.165 m.e. are magnesium and 2.45 m.e. are hydrogen.

The seven systems of cropping are being conducted at two fertility levels. The plots are randomized with respect to systems of cropping and fertilizer levels and are replicated four times. Each crop is grown each year. For this study only the results from the high-fertility plots were considered, in order to be sure that fertility conditions did not limit crop growth.

The crop sequence in the seven systems of farming is as follows:
Rotation 1—Barley, alfalfa-brome, alfalfa-brome, corn, sugar beets.
Rotation 2—Barley, alfalfa-brome, alfalfa-brome, sugar beets, corn.
Rotation 3—Barley, alfalfa-brome, alfalfa-brome, beans, sugar beets.

[1] Contribution from the Department of Soil Science, Michigan Agricultural Experiment Station, East Lansing, Michigan. Authorized for publication by the Director as Journal Article No. 1330 of the Michigan Agricultural Experiment Station. The data presented in this paper are taken from a thesis being prepared for presentation to the faculty of the Graduate School, Michigan State College, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Appreciation is expressed to the Farmers and Manufacturers Beet Sugar Association for financial assistance in this experiment and to Professor R. W. Bell of the Farm Crops Department for assistance and advice, and for the presentation of the paper.

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Rotation 4—Barley, oats, alfalfa-brome, corn, sugar beets.
Rotation 5—Barley, oats, clover-timothy, corn, sugar beets.
Rotation 6—Barley, beans, wheat, corn, sugar beets.
Rotation 7—Barley, green manure[3], beans, wheat, green manure[3], corn, sugar beets.

The green manure crops are seeded in the barley and wheat and are plowed under for beans and corn respectively the following spring. The sugar beets and grain in each rotation receive equal amounts of commercial fertilizer, 1,000 pounds per acre in five years. The beet crop receives 500 pounds and the balance is applied for grain. In the rotations which include two grain crops, each one received 250 pounds per acre. The fertilizer is 2-16-8. A complete description of the field layout was published in the 1946 Proceedings of the American Society of Sugar Beet Technologists.

Table 1.—The Effect of Systems of Farming on Sugar Beet Yields.

Rotation number	Crop Sequence[1]	Yield per acre-tons							
		1946	1947	1948	1949	1950	1941-1945 Means	1946-1950 Means	1941-1950 Means
1	Ba-A-A-C-SB	12.87	0.00	12.33	9.00	11.08	10.34	9.06	9.70
2	C-Ba-A-A-SB	16.76	0.00	8.86	8.32	8.04	10.88	8.40	9.64
3	Ba-A-A-Be-SB	15.36	0.00	12.33	10.09	10.57	10.24	9.67	9.96
4	Ba-O-A-C-SB	14.31	0.00	11.67	8.69	9.75	10.45	8.88	9.67
5	Ba-O-Cl-C-SB	13.22	0.00	11.46	10.05	9.10	10.04	8.77	9.41
6	Ba-Be-W-C-SB	11.26	0.00	10.66	8.77	8.81	9.64	7.90	8.79
7	Ba(gm)-Be-W-(gm)-C-SB	13.01	0.00	11.64	8.79	10.49	10.08	8.79	9.44

[1] Ba—barley, Be—navy bean, A—alfalfa-brome hay, C—corn, O—oats, W—Wheat, SB—sugar beet, Cl—clover-timothy hay, gm—green manure mixture—Alsike, June, Sweet clover.

Experimental Procedure

Dry screen analyses of the seed beds were made on screens having mesh sizes ranging from 2 inch to ⅛ inch and measuring approximately 2 x 4 feet in size. The screens were made especially for this purpose. Soil was sampled with a small square-nosed spade to a depth of 3 inches at 20 random locations on each plot the day after the crop was planted. A weighed sample of soil was placed on the top (largest) sieve. That which remained on each sieve was removed and weighed. By calculation, the portion which passed through the finest sieve was determined.

Aggregate analyses were made in a laboratory-made wet sieving apparatus by the principle outlined by Yoder (5).[4] Composited soil samples from each plot were collected after planting the crop but previous to the first cultivation. The soil was partially air dried and passed through a 10-mm. screen. The soil was then completely air dried and the material finer than 5 mm. was removed by screening. The 5 to 10 mm. soil material was then used for aggregate analysis.

Samples for porosity determinations were collected during the growing season. The determinations were made on a pF table similar to the ones described by Leamer and Shaw (3).

Penetrometer records were obtained with a self-recording penetrometer designed by Robertson and Hansen (4).

[3] Mixture of alsike, June, mammoth and sweet clovers.
[4] Numbers in parentheses refer to literature cited.

Experimental Results

The yield data during the period 1946 through 1950 reported in this paper vary slightly from those reported elsewhere. This is because of a variation in the exact areas harvested on the plots used in this study. Attention is called also to the fact that this study involves only those plots which received the larger applications of fertilizer.

Sugar beet yields, as shown in Table 1, have varied considerably from year to year. No yields were obtained in 1947 because black root destroyed the stand. Severe infestations also occurred in 1948, 1949 and 1950, but the beets partially recovered and produced yields about average for the area. At the end of the first cycle of the rotations, the no-legume system of farming (rotation 6) had resulted in yields actually smaller than those recorded for the other systems but the difference was not statistically significant.

Table 2.—The Effect of Systems of Farming on Corn Yields.

Rotation number	Crop Sequence[1]	Yield per acre-bushels							
		1946	1947	1948	1949	1950	1941-1945 Means	1945-1950 Means	1941-1950 Means
1	SB-Ba-A-A-C	58.2	52.7	48.8	99.0	64.2	44.8	64.58	54.69
2	Ba-A-A-SB-C	53.7	32.6	60.0	87.3	58.5	39.7	58.44	49.07
4	SB-Ba-O-A-C	62.9	48.1	50.0	98.8	63.1	45.8	64.58	55.19
5	SB-Ba-O-Cl-C	59.1	44.4	33.3	94.7	63.1	40.7	58.92	49.81
6	SB-Ba-Be-W-C	40.8	30.8	26.0	62.9	50.1	33.8	42.12	37.96
7	SB-Ba(gm)-Be-W(gm)-C	54.1	37.3	42.7	86.2	55.9	40.5	55.24	47.87
	Significance	**	**	**	**	**	**	**	**
	L.S.D. at 5%	9.7	5.4	10.5	15.2	12.1	4.2	4.8	3.0

Analysis of the results obtained during the second cycle of the rotations indicates that a significant difference did exist between yields in that rotation and those obtained in the livestock system of cropping where beans preceded sugar beets (rotation 3). The analysis of the data from the two cycles of crop rotation shows that the four rotations which grew alfalfa-brome hay were all superior, as measured by sugar beet yields, to the one which did not include a legume. The effect of clover-timothy hay (rotation 5) on sugar beet yields was about equal to the effect of the two green manure crops in rotation 7. Each of these legumes proved to be slightly inferior to the alfalfa-brome hay.

The corn yield data are shown in Table 2. A significant difference in yield occurred each year and the differences in yield were consistent year after year. The corn yields seemed to arrange themselves into three groups. Where corn followed wheat with no legume in the rotation the yields were the lowest in the experiment every year during the 10-year period.

The second group included three rotations, where corn followed sugar beets (rotation 2), where it followed clover-timothy hay (rotation 5) and where it followed wheat which was seeded with a leguminous green manure mixture (rotation 7). The corn yields in these three rotations were consistently better than in the depleting rotation (rotation 6), but were lower

than where corn followed alfalfa. The one inconsistent figure, that for rotation 2 in 1948, was the result of the sugar beet failure in 1947. Thus, in 1948, corn on these plots actually followed summer fallow, which in turn had followed alfalfa, instead of following sugar beets.

The highest corn yields occurred where the crop followed immediately after alfalfa. There was no consistent difference between the effects of one and two years of alfalfa-brome hay. The yields from these two rotations (rotations 1 and 4) were significantly higher than where corn followed clover-timothy, sugar beets, or wheat.

The results of the dry screen analyses of the sugar beet and corn seed beds are shown in Table 3. Crop rotations caused no differences in these results for the sugar beet seed beds. Rotation did affect the size distribution of the aggregates in the corn seed beds in that the soil subject to the cash crop rotation contained more large clods than did that subject to any of the other systems of farming. The seed bed in this rotation contained even

Table 3.—The Effect of Systems of Farming upon Dry Screen Analyses of Sugar Beet and Corn Seed Beds in 1949.

Rotation number	Crop Sequence	Sugar Beet Seed Beds Percent of Aggregates retained on the Screen Indicated[1] 2 inches	2-1 inches	1-½ inches	½-¼ inches	½-⅛ inches	⅛ inches
1	Ba-A-A-C-SB	4.2	14.3	13.0	16.5	15.7	36.3
2	C-Ba-A-A-SB	2.1	8.4	11.0	18.7	21.5	38.0
3	Ba-A-A-Be-SB	4.8	10.2	12.4	16.7	16.3	39.6
4	Ba-O-A-C-SB	2.8	9.2	12.3	18.1	17.6	40.0
5	Ba-O-Cl-C-SB	3.7	10.8	13.1	18.5	19.5	34.4
6	Ba-Be-W-C-SB	2.6	8.7	13.2	18.4	17.5	39.6
7	Ba(gm)-Be-W-(gm)-C-SB	3.7	11.2	12.8	17.4	15.8	39.1

Rotation number	Crop Sequence	Corn Seed Beds Percent of Aggregates retained on the Screen Indicated[1] 2 inches	2-1 inches	1-½ inches	½-¼ inches	½-⅛ inches	⅛ inches
1	SB-Ba-A-A-C	0.3	7.3	10.0	18.0	20.1	44.3
2	Ba-A-A-SB-C	0.0	15.2	15.0	16.8	15.3	37.7
4	SB-Ba-O-A-C	0.7	7.8	13.9	23.7	17.9	36.0
5	SB-Ba-O-Cl-C	0.0	4.0	11.8	22.4	19.6	42.2
6	SB-Ba-Be-W-C	3.1	13.0	19.4	21.5	14.6	28.4
7	SB-Ba(gm)-Be-W(gm)-C	1.3	7.3	14.9	23.0	17.5	36.0

[1] Average of 4 determinations—one from each plot replication.

more of the larger aggregates than did the soil in the sugar beet seed beds. While these analyses were run only in 1949, observations have indicated that such conditions did exist during the other seasons. The large clods on the rotation 6 plots were probably not stable aggregates. This is indicated by the aggregate analysis data obtained later in the season.

The results of the aggregate analyses of the corn and sugar beet root beds during 1947 are shown in Table 4. The results of other years, in general, are in agreement with these data.

Considering the soil from the corn plots, that from the rotations which included the legume-grass hays contained greater percentages of the large aggregates and the aggregates were more stable. The data for 1947 suggest that one year of hay in a rotation results in more water stable aggregates than does two years of hay. This conclusion, however, was not justified by the results of other year's data not reported herein. Also, observations made at various times during the year do not justify this conclusion. In general, the soil from the cash crop rotation was less stable and was aggregated to a lesser degree than was the soil from any of the other rotations.

The aggregate analysis results obtained on the soil from the sugar beet plots show that little difference in aggregate existed among rotations 1, 3, 4,,5, 6 and 7. In rotation 2 (beets after alfalfa), the soil was more stable and better aggregated than was the soil in the other rotations. This is in agreement with the observations which have been made by the beet workers at blocking and thinning time and during cultivation.

If the aggregate analysis results on the corn and beet soils are compared with those on soil under sod located in a little used alleyway adjacent to the plots, the potential value of grass as an aggregating agent is fully

Table 4.—The Effect of Systems of Farming upon Aggregate Analysis of Corn and Sugar Beet Root Beds in 1947.

Rotation number	Crop Sequence	Corn Root Beds: Percent of aggregates retained on the screen indicated						
		10-4 mm.	4-2 mm.	2-1 mm.	1-.5 mm.	.5-.25 mm.	.25-.10 mm.	less. .1 mm.
1	SB-Ba-A-A-C	8.0	6.6	6.7	14.6	22.5	22.6	19.0
2	Ba-A-A-SB-C	8.1	6.6	6.6	13.2	26.1	20.8	18.6
4	SB-Ba-O-A-C	15.1	7.7	55.7	15.4	20.0	14.8	21.3
5	SB-Ba-O-Cl-C	10.5	8.9	6.2	11.2	22.4	22.0	18.8
6	SB-Ba-Be-W-C	2.6	4.6	4.8	9.5	24.2	31.9	22.4
7	SB-Ba(gm)-Be-W-(gm)-C	8.6	5.3	5.4	11.8	26.0	24.0	18.9

Rotation number	Crop Sequence	Sugar Beet Root Beds: Percent of aggregates retained on the screen indicated						
		10-4 mm.	4-2 mm.	2-1 mm.	1-.5 mm.	.5-.25 mm.	.25-.10 mm.	less. .1 mm.
1	Ba-A-A-C-SB	5.4	8.1	5.8	10.4	22.9	24.2	23.2
2	C-Ba-A-A-SB	10.6	7.9	5.7	9.9	21.1	22.5	22.3
3	Ba-A-A-Be-SB	5.0	7.6	5.5	9.6	22.5	25.4	24.4
4	Ba-O-A-C-SB	8.1	7.0	5.7	9.8	19.2	21.9	28.3
5	Ba-O-Cl-C-SB	6.9	7.1	5.2	10.6	21.1	24.3	24.8
6	Ba-Be-W-C-SB	6.3	6.8	5.7	9.9	22.8	25.5	23.0
7	Ba(gm)-Be-W-(gm)-C-SB	7.4	10.5	6.0	10.2	21.1	21.7	23.1
	Grass	36.6	10.4	8.4	8.9	11.7	8.1	15.9

realized. Inspection of the screens during the time the analyses were made showed clearly the mechanical effect of the grass roots in binding some of the smaller aggregates together to form larger ones.

The porosity data from the corn plot soils are shown in Table 5. These data suggest that there was no difference in the early part of the growing season in 1947, but that, as the season progressed, differences did occur. The soil in the plots where legumes are not grown (rotation 6) contained sig-

nificantly less total pore space than did the soils in the green manure rotation plots.

No significant differences are evident in the non-capillary pore space data obtained in 1947. Perhaps too few determinations were made on each plot. In 1948, all of the soils subject to the livestock system of farming (rotations containing hay), except those where the hay was clover-timothy, had higher non-capillary porosity than did the soils where hay crops had not been grown (rotations 6 and 7). The soils of the clover-timothy rotation (rotation 5) contained greater percentages of non-capillary pore space than did the soils on the plots where no soil-building crops are grown.

Porosity determinations were made on the sugar beets soils in 1947 despite the fact that no crop was harvested. The June 12 sampling (Table 6) occurred before the beets were replanted. While there was a statistically significant difference in percent total pore space at that time, the differences are difficult to interpret because they do not agree with observation or yield determinations. After the beets were replanted, all of the plots had similar characteristics in regard to pore space.

Table 5.—The Effect of Systems of Farming upon the Total and Non-Capillary Pore Space of the Soil in the Corn Plots.

		Percent pore space on the sampling dates indicated					
		Total			Non-Capillary		
Rotation number	Crop Sequence	July 15 1947	Oct. 15 1947	Oct. 1948	June 15 1947	Oct. 15 1948	Oct. 1948
1	SB-Ba-A-A-C	45.8	48.2	50.3	11.3	10.8	10.4
2	Ba-A-A-SB-C	45.2	45.8	49.3	9.4	8.9	9.7
4	SB-Ba-O-A-C	45.0	49.0	48.8	12.2	9.9	9.8
5	SB-Ba-O-Cl-C	46.0	49.3	48.4	12.3	9.4	9.0
6	SB-Ba-Be-W-C	44.5	43.9	45.4	10.4	5.7	7.7
7	SB-Ba(gm)-Be-W-(gm)-C	45.1	46.8	47.4	11.9	9.4	8.7
	Significance	—	••	••	—	—	••
	L.S.D.	N.S.	2.5	1.4	N.S.	N.S.	0.9

Table 6.—The Effect of Systems of Farming upon the Total and Non-Capillary Pore Space of the Soil in the Sugar Beet Plots.

		Percent pore space on the sampling dates indicated							
		Total				Non-Capillary			
Rotation number	Crop Sequence	June 12 1947	June 17 1947	Sept. 25 1947	Oct. 1948	June 12 1947	July 17 1947	Sept. 23 1947	Oct. 1948
1	Ba-A-A-C-SB	48.5	52.6	46.3	46.4	17.1	23.5	14.2	9.7
2	C-Ba-A-A-SB	53.8	50.6	50.7	50.0	23.1	19.8	21.3	13.5
3	Ba-A-A-Be-SB	51.1	53.0	46.6	45.7	16.6	24.2	14.2	11.2
4	Ba-O-A-C-SB	52.3	53.1	44.6	45.5	21.7	22.9	12.3	10.0
5	Ba-O-Cl-C-SB	52.0	54.5	47.3	47.3	19.4	24.2	14.1	9.0
6	Ba-Be-W-C-SB	53.9	53.8	45.2	41.4	20.0	23.4	9.5	7.5
7	Ba-(gm)-Be-W-(gm)-C-SB	49.2	52.8	44.2	44.9	17.7	23.1	10.9	9.8
	Significance	•	—	••	••	—	—	••	••
	L. S. D.	2.7*	N.S.	3.2	2.6	N.S.	N.S.	4.5	2.1

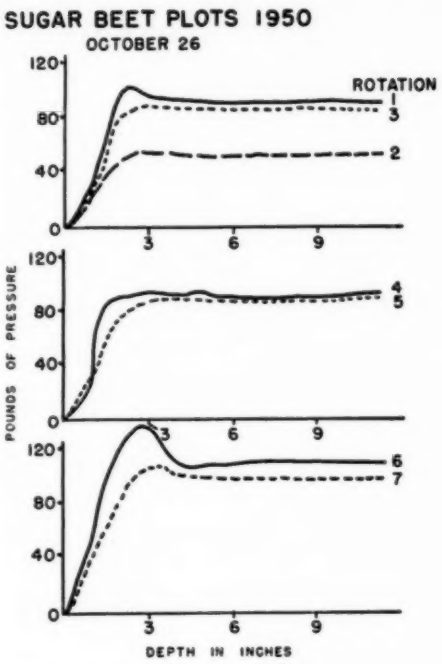

Figure 1. Penetrometer records from the 1950 Sugar Beet Plots comparing rotations 1, 2, 3, 4, 5, 6 and 7.

In the latter part of the 1947 and 1948 seasons, differences were found in both total and non-capillary pore space. This suggests that crop rotations caused differences in aggregate stability. The desirable effect of a hay crop (rotation 2) is evident in the total porosity data. Where a corn crop had been grown since the hay crop was plowed under, the pore space was significantly reduced. In 1948 the soil where legumes have not been grown during the experiment had the lowest percentage pore space, both total and non-capillary. That soil had the lowest percentage of non-capillary pore space also in 1947. Apparently, soil structure has reached an unstable state in that soil.

Perhaps one of the reasons why an increase in pore space, especially non-capillary, results in greater yields is that nitrification may take place more rapidly. The relationship between soil structure and nitrification was suggested by the data of Doiarenko (reported by Baver (1)) who found that non-capillary porosites of 2.7, 24.5, 35.1 and 38.7 percent resulted in the formation of 9.0, 19.1, 34.0 and 45.8 mgms. respectively of nitrogen as nitrate. Thus, the production of legumes not only supplies more nitrogen but soil porosity is increased and nitrification goes on at a more rapid rate.

A sample of the penetrometer records is shown in Figures 1, 2 and 3. The curves show that rotation and crop sequence have influenced the depth of the crust which formed on the soil surface after cultivation was completed.

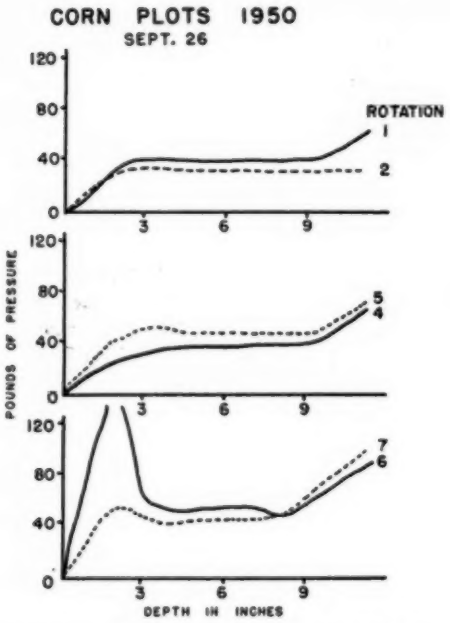

Figure 2. Penetrometer records from the 1950 Corn Plots comparing rotations 1, 2, 4, 5, 6 and 7.

The curves in Figure 3 show that the differences recorded by the penetrometer did not show up until late in the season. This was probably due largely to the cultivation. It may have been due partly to differences in water stability. As the season progressed, aggregates would more completely break down where structure was weak.

Summary

Seven Michigan systems of crop rotation and sequence were laid out in 1940 as an experiment on Brookston sandy clay loam. The primary purpose was to determine the value of legumes and legume grass mixtures in the production of sugar beets, corn, beans and the small grains. Major emphasis was placed on the beet crop. Plots were replicated four times and all crops occurred each year.

In addition to yield measurements, certain physical studies have been made on the soils. These have included dry screen analyses of seed beds, aggregate analyses of root bed soils and porosity determinations made on core samples.

The production of alfalfa-brome hay in the rotation caused significant increases in yields of sugar beets. One year of hay was as beneficial as two. The highest yields of beets were obtained on plots where the crop followed beans which had followed alfalfa-brome. As a nine-year average, beets following corn, which in turn had followed alfalfa, produced yields equal to those produced by beets directly following alfalfa.

Two mixed clover green manure crops were about equal to one year of red clover-timothy hay as they affected sugar beet yields. The clovers were slightly inferior to alfalfa-brome.

Corn yields were markedly increased by the production of legumes and legume-grass mixtures in the rotation. Highest yields occurred where corn followed alfalfa-brome, either one or two years of hay. Somewhat lower yields resulted where corn followed the clovers or where sugar beets were grown between the alfalfa-brome and the corn. Very small crops have been harvested where corn was grown on plots which for eleven years have not grown a soil-building legume.

The soil-building crops have changed the structure of the soil. The dry screen analyses showed that soils prepared for corn contained more large clods where legumes had not been grown.

Aggregate analyses made on soil from corn plots showed that the soil on the plots where alfalfa-brome had been grown contained more of the

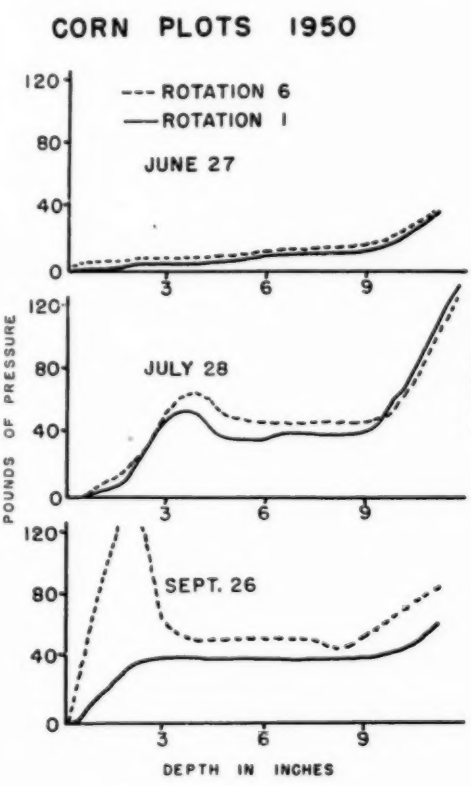

Figure 3. Penetrometer records from the 1950 corn plots comparing the soil in rotations 1 and 6 during the growing season.

large aggregates and more stable aggregates than did that from plots which had not produced a legume.

At the time of sugar beet planting, the soil on the plots which had grown alfalfa the previous year was in a more stable state of aggregation than that on any other plots.

Percentage pore space, both total and non-capillary, was increased by the production of legumes. Differences in pore space were greater during the later part of the growing season than at the beginning of the season.

Penetrometer studies showed that a hard crust formed at the surface of soils which had not raised a soil-building crop, but did not form to any appreciable extent where legumes had been grown.

Since greater yields and improved soil structure were the result of the cropping system, it may be true that some of the increase in yield was due to the improved structure.

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The Relative Feeding Value of Dried Molasses Beet Pulp Produced with Various Types of Saccharate Filtrates

W. E. CONNELL[1]

Recently there has been greatly increased interest in the nutritional value of certain saccharate filtrates which for many years have been, and, in many instances, are still being discarded in the process of manufacturing refined beet sugar.

While the recovery of specific substances of commercial value separable from these saccharate filtrates, such as potash and glutamic acid, have stimulated this interest, the growing need to reduce the amount of so-called waste end products from commercial plants has also emphasized the urgency of determining the value of these by-products.

The so-called saccharate filtrates referred to in these studies are most commonly called Johnstown "B" molasses or Johnstown feeder molasses; concentrated Steffen's Filtrate or C.S.F.; and "G.A." mother liquor, which consists of the end liquor derived from beet molasses in the glutamic acid extraction process, either neutralized with lime to 7.0 pH or at 3.2 pH, respectively.

For the cattle feeding tests described herewith, these four saccharate filtrates were all desalted and were then dried on beet pulp to provide 20 percent dry substance respectively of the dried molasses beet pulp produced for the trials, which pulp was designated respectively "B" Molasses pulp, No. 1 Hi-pro pulp for the "C.S.F." pulp, No. 2 Hi-pro pulp for the neutralized G.A. end liquor pulp, and M.C. 47[2] pulp for the acid G.A. end liquor pulp.

Johnstown "B" molasses, or Johnstown feeder molasses, as it is called at present, the saccharate filtrate recovered from the Johnstown, Colorado, plant of the Great Western Sugar Company, has been used successfully both as a feeding supplement and dried on beet pulp since 1935, or for the past 17 years. The other saccharate filtrates had not been dried on beet pulp prior to these tests.

In the first fattening test with yearling steers conducted at the Colorado A & M College Experiment Station for a period of 154 days during the winter of 1950-51, the dried molasses beet pulp products were fed as one-third by weight of the grain ration, mixed with ground shelled corn. The balance of the ration consisted of corn silage, soybean meal, baled alfalfa hay and salt.

The second fattening test, conducted at the Windsor, Colorado, farm of the Great Western Sugar Company under the supervision of the Colorado Experiment Station, was also carried on with yearling steers and for a period of 186 days. In this test the dried molasses beet pulp products were fed as one-half by weight of the grain ration, and were mixed with ground barley. The balance of the ration consisted of ground alfalfa hay, soybean meal and salt.

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[1] Animal Husbandman, Colorado Experiment Station, Colorado A & M College.

[2] M.C. 47 was supplied by International Minerals and Chemical Company, Jan Jose, California.

Table 1.—The Relative Feeding Value of Dried Molasses Beet Pulp Produced with Various Types of Saccharate Filtrates. Experiment No. 1, Animal Investigations Section[1], Colorado A & M Experiment Station, Fort Collins Colorado. Steers Fed 150 Days—October 24, 1950, to March 27, 1951. (Table based on one average steer)

Lot Number	1	2	3	4
Number of Steers	9	9	9	9
Rations Fed:[2] Salt self-fed in all lots	B. Mol. Pulp Gr. Corn S.B. Meal Corn Sil. Bal. Alf.	No. 1 Hipro Pulp Gr. Corn S.B. Meal Corn Sil. Bal. Alf.	No. 2 Hipro Pulp Gr. Corn S.B. Meal Corn Sil. Bal. Alf.	MC 47 Pulp Gr. Corn S.B. Meal Corn Sil. Bal. Alf.
Initial Wt. (Feedlot)	877	875	876	879
Market Wt. (Denver)	1,218	1,222	1,201	1,208
Total Gain	341	347	325	329
Daily Gain	2.21	2.25	2.11	2.14
Average Daily Ration:				
B Molasses Pulp	5.62			
No. 1 Hipro Pulp		5.44		
No. 2 Hipro Pulp			5.17	
MC 47 Pulp				5.44
Ground Corn	11.66	11.31	10.75	11.29
Soybean Meal	.92	.92	.91	.92
Corn Silage	8.13	8.04	8.03	8.13
Baled Alfalfa	3.46	3.46	3.39	3.42
Salt	.01	.02	.02	.02
Feed Required per Cwt. Gain:				
B Molasses Pulp	253			
No. 1 Hipro Pulp		242		
No. 2 Hipro Pulp			245	
MC 47 Pulp				254
Ground Corn	526	502	510	528
Soybean Meal	41	41	43	43
Corn Silage	367	357	381	380
Baled Alfalfa	156	154	161	160
Salt	.7	.8	1.0	.9
Feed Required per Cwt. Gain:	27.39	26.34	26.99	27.67
Market Value (Denver)	37.05	37.25	36.85	37.05
Selling Price Needed to Cover Steer and Feed Cost	29.26	28.96	29.19	29.37
Carcass Yield	61.8	64.2	62.6	63.5
Carcass Grade:				
Prime	1	2	1	
Choice	8	7	7	9
Good			1	

[1] In cooperation with Great Western Sugar Co., Denver, and with International Minerals and Chemical Corporation, Chicago, Ill.

[2] Feed Costs Used: B Molasses Pulp at $39.50 T; No. 1 Hipro Pulp at $39.50 T; No. 2 Hipro Pulp at $39.50 T; MC 47 Pulp at $39.50 T; Ground Corn at $61.00 T; Soybean Meal at $95.00 T; Corn Silage at $12.00 T; Baled Alfalfa at $27.00 T; and Salt at $21.00 T.

Table 2.—The Relative Feeding Value of Dried Molasses Beet Pulp Produced with Various Types of Saccharate Filtrates. Experiment No. 2, Animal Investigations Section, Colorado A & M Experiment Station, Fort Collins, Colorado.[1] Fed 186 days—Dec. 20, 1950, to June 24, 1951. (Table based on one average steer)

Lot No.	1	2	3	4
Number of steers	19	20	20	20
Rations Fed:[2] Salt self-fed in all lots	Gr. Barley B. mol. pulp S.B. meal Gr. alf.	Gr. Barley No. 1 Hipro S.B. meal Gr. alf.	Gr. Barley No. 2 Hipro S.B. meal Gr. alf.	Gr. Barley MC 47 pulp S.B. meal Gr. alf.
Initial Wt. (Feedlot)	693	692	685	693
Market Wt. (Denver)	1,082	1,087	1,077	1,096
Total Gain	389	395	392	403
Daily Gain	2.09	2.12	2.11	2.17
Average Daily Ration:				
Ground barley	7.62	7.81	7.55	7.94
"B" Mol. beet pulp	7.62	-----	-----	-----
No. 1 Hipro pulp	-----	7.81	-----	-----
No. 2 Hipro pulb	-----	-----	7.55	-----
MC 47 pulp	-----	-----	-----	7.94
Ground alfalfa	5.28	5.42	5.39	5.42
Soybean meal	.97	1.00	1.00	1.00
Salt	.03	.03	.04	.02
Feed Required per Cwt. Gain				
Ground barley	364	368	358	367
"B" Mol. beet pulp	364	-----	-----	-----
No. 1 Hipro pulp	-----	368	-----	-----
No. 2 Hipro pulp	-----	-----	358	-----
MC 47 pulp	-----	-----	-----	367
Ground alfalfa	252	255	256	250
Soybean meal	46	47	47	46
Salt	1.5	1.5	1.7	.9
Feed Cost per Cwt. Gain	$23.16	$23.41	$22.94	$23.21
Market Value (Denver)	$36.45	$36.61	$35.97	$36.15
Carcass yield	62.56	63.02	61.98	62.19
Carcass Grade:				
Prime	14	13	12	13
Choice	5	7	8	7

[1] In Cooperation with Great Western Sugar Company, Denver, Colorado.

[2] Feed Costs Used: Ground Barley at $55.00 T; B. Molasses Pulp at $39.50 T; No. 1 Hipro Pulp at $39.50 T; No. 2 Hipro Pulp at $39.50 T; MC 47 Pulp at $39.50 T; Gr. Alfalfa at $29.50 T; Soybean Meal at $955.00 T; Salt at $21.00 T.

Table 3.—Analysis of Dried Molasses Beet Pulp Used in Cattle Feeding Tests.

	Johnstown "B" Molasses Pulp		"C.S.F." Hipro No. 1 Molasses Pulp		Neutral G.A. End Liquor Hipro No. 2 Molasses Pulp		Acid G.A. End Liquor, M.C. 47 Molasses Pulp	
	% on Orig.	% on Dry Sub.	% on Orig.	% on Dry Sub.	% on Orig.	% on Dry Sub.	% on Orig.	% on Dry Sub.
Moisture	5.0	.....	5.4	.....	5.1	.....	4.9	.....
Ash	7.6	8.0	7.7	8.1	6.2	6.6	7.2	7.6
Crude Protein	9.7	10.2	12.7	13.4	13.2	13.9	13.6	14.3
Crude Fat	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Crude Fiber	19.4	20.5	18.9	20.0	21.0	22.1	19.6	20.6
N. Free Extract	58.1	61.1	55.1	58.3	54.3	57.2	54.5	57.3

Detailed data secured in these two feeding experiments are included in the tables presented herein. While there were no really significant differences shown in the average rate of gain secured on the different lots of animals fattened, the Hi-pro No. 1 lot, fed dried molasses pulp produced with the concentrated, desalted Steffen's filtrate did produce the heaviest average daily gains, or 2.185 pounds per head per day, while this same pen also showed the highest dressing percentage or carcass yield for an average of 63.61 percent.

The really significant fact developed by these two cattle fattening experiments was that any one of these saccharate filtrates could be used successfully in the production of dried molasses beet pulp, and that a 20 percent dry substance molasses pulp produced with any of them could be expected to produce as good results as have been secured during the past 17 years with the standard dried molasses beet pulp produced with Johnstown feeder molasses.

Pelleting Dried Molasses Beet Pulp

E. J. MAYNARD[1]

The processing of dried molasses beet pulp into small sized pellets suitable for mixing with grain to feed in troughs to cattle or sheep has proved to be a sound and worthwhile development.

This pelleting operation compresses dried pulp to approximately one-fifth and dried molasses beet pulp to nearly one-fourth its original size. It converts this extremely bulky concentrate into a compact, pelleted product which is easy to handle and convenient to store, to haul and to feed.

More than twenty thousand tons of these small, three-eighths inch diameter molasses pulp pellets have been produced and sold to cattle and sheep feeders in Great Western Sugar Company territory during the past two years, and the pelleted product, which is free from fines and dust, has proved extremely popular with the farmers and livestock feeders who have used it.

While the larger three-quarter inch diameter beet pulp pellets, composed of a mixture of several ingredients, to provide a balanced concentrate for wintering range livestock, have been produced by this company at its Billings, Montana, plant for the past 18 years, the processing of dried molasses beet pulp alone with no added ingredients into these small pellets suitable for bulk feeding is a comparatively new venture. For this reason, there are still certain production and feeding problems involved which will require solution before their most effective production and universal acceptance can be assured.

For some time attempts have been made to process dried beet pulp into a more compact product. The object has been to get away from its extreme bulk, to eliminate need for the large sacks and excessive storage space required in handling it, and also to eliminate its tendency to blow when fed in open bunks.

It has been demonstrated conclusively that the high absorptive capacity of dried pulp, which is a nutritional factor with recognized physiological value, is not impaired by increasing the density of the product, either by grinding or compressing it.

At one location today, the entire production of dried molasses beet pulp is being rolled through corrugated steel rolls to reduce its volume by breaking up the crinkly, dried cossettes into shorter lengths; in other words, "by taking the crinkles out of it." This process has made possible the reduction of burlap bag requirements for packing 100 pounds of this dried molasses beet pulp by about 25 percent, or from 54-inch material cut 72 inches to 45-inch material cut 66 inches, **and with no appreciable difference in the quality or physical consistency of the product.**

In some few instances, dried beet pulp has been milled; that is, ground up or hammered to a powdery consistency to save storage space where it

[1] General Livestock Consultant, the Great Western Sugar Company.

has been destined for future use as an ingredient in pelleted commercial mixed feeds.

It is interesting to note that during the past season blocks or briquets of dried molasses beet pulp have been produced at the Wissington factory of the British Sugar Corporation. (1)[2] These blocks, 12½ inches by 9 inches by 4½ inches in size, with an approximate weight of 8½ to 10 pounds, naturally occupy less space than bulk pulp. They weigh approximately 31.5 pounds per cubic foot. They are generally soaked before being fed and are said to disintegrate in water after only ten minutes soaking, absorbing about three gallons each.

While such briquets might prove suitable for use in some dairy rations or in purebred beef cattle or sheep rations where it is customary to soak the dried beet pulp before feeding it, they would not seem to be very satisfactory for use in dry grain-beet pulp, self-fed mixtures which are at present the general rule in fattening cattle or sheep in this western area.

The significant advantage derived from pelleting dried beet pulp is shown in Table 1 comparing weights per cubic foot and average weights per bushel of the various dried beet pulp products containing approximately 20 percent dry substance Johnstown feeder molasses, and manufactured by the Great Western Sugar Company.

Table 1.

	Weight per Cubic Foot	Average Weight per Bushel
	Pounds	Pounds
Plain dried beet pulp	8 to 10	11.2
Dried molasses beet pulp	11 to 13	14.9
Dried molasses beet pulp (Rolled through corrugated steel rolls)	16 to 18	21.1
Dried molasses beet pulp (Milled with hammer mill)	24 to 28	32.4
Molasses pulp pellets (⅜ inch diameter)	42 to 48	56.0

The most recent and satisfactory development in producing a compact dried pulp product, and one which can be produced and sold locally and entirely in bulk, has been the production of these ⅜ inch molasses pulp pellets.

This operation was conducted in Great Western Sugar Company territory at the Loveland, Colorado, plant during the 1950 and 1951 campaigns, and at the Ovid, Colorado, and Gering, Nebraska, plants during the 1951 campaign.

While the company has produced an average of some 3,000 tons of range pellets annually at its Billings plant during the past 18 years, these large pellets made in ¾ inch diameter size and composed of a mixture of dried beet pulp, molasses, protein concentrates and bone meal, have been compounded as a balanced concentrate, primarily for use as a supplement to be fed to cattle and sheep out on winter range, and while they have

[2] Numbers in parentheses refer to literature cited.

proved successful in competition with other range concentrates, they have proved too large for general acceptance in feed lot rations. Sold mostly to range stockmen, they have accomplished little in stimulating livestock feeding or the increased production of fertility in beet growing areas.

On the other hand, these much smaller molasses pulp pellets produced from dried molasses beet pulp alone, with only the addition of enough moisture and steam required to moisten the pulp for the pelleting operation, and sold on the basis of a bulk dried pulp price plus the cost of pelleting, have proved well adapted for use in grain mixtures for the trough or bunk feeding of fattening cattle and sheep, and for dairy cows. Up to the present time these pellets have been sold only to beet growers and commercial livestock feeders in beet growing areas and entirely in bulk.

They weigh as much as shelled corn per bushel, and can be handled and stored as easily as bulk shelled corn. They should eliminate the need for sacks, and because of the economy in handling them they should facilitate a much wider distribution of this dried pulp product within the beet growing areas.

The average beet grower, who at present can haul only about 1½ tons of bulk dried pulp in his beet rack, and who must cover even this small load to prevent excessive blowing enroute, will now be able to safely haul some five to six tons of these pellets with the same equipment. He will be able to store this product in much less bin space, and will no longer need to worry about feed losses from blowing when he mixes and distributes this feed in his troughs.

One criticism of these beet pulp pellets which has been rather frequently heard when they are first used has been that they are extremely hard. As a matter of fact, they are about twice as hard as ordinary grain or meal pellets, but in this case this hardness is not a disadvantage. It is due principally to the extremely yielding character of the crude fiber in dried beet pulp which is as highly digestible as nitrogen free extract in grain, and to the very low pressure required to compress and compact it when in a moist condition. These pellets are easily crumbled when they first come hot through the dies, but in the course of a few minutes they become very hard as they cool and dry.

It is a well established fact, however, that ruminants do not chew their food when they first ingest it, but instead simply swallow it and only masticate it thoroughly later on when they are ruminating or chewing their cud. Under such circumstances, these beet pulp pellets absorb moisture in the paunch, quickly soften up and disintegrate, swelling to some 17 times their original size, and exert their characteristic beneficial effect on general digestion.

However, the production of straight molasses pulp pellets seems fraught with operating difficulties which cause excessive wear on expensive dies and uncertain production rates. What are some of these production difficulties and how may they be overcome? What is sound policy as to size and constituency in the production of beet pulp pellets? These are questions which need more careful study at the present time.

In the first place, molasses beet pulp as it comes from the drier tends to be more corrosive and abrasive than ordinary grain by-product feeds which are milled and pelleted. This may not be due to the pulp itself, but rather to foreign material which has not been thoroughly excluded from the beet pulp, or to fly ash from coal used in the dehydration process, or to both these factors. If this problem cannot be overcome by elimination of these impurities, then the matter of including some other feed ingredient of a sirupy or oily nature needs consideration.

It has been generally conceded that the processing of straight dried molasses pulp into small enough pellets to be mixed with grain for bunk feeding would be most advantageous, and that the use of available beet by-products such as beet molasses or saccharate filtrates would be most efficient in this pellet production. However, the mixed feed manufacturer and pelleter uses molasses high in sugar, or oily protein concentrates to control the hardness of his pellets, and consistently mills all ingredients through hammer mills to insure minimum wear on expensive dies. He is not faced with the 24-hour around-the-clock production required by the sugar producing "campaign."

Then, too, the very character and physical consistency of the fiber in dried beet pulp is distinctly changed by the condition of the sugar beets at the time they are sliced. Early in the fall when fresh beets are being sliced, this fiber is spongy and resilient, while later on the same fiber has often lost these characteristics and becomes greasy and non-resilient, requiring more heat for drying and different techniques for pelleting.

These factors all add up to the necessity for more rigid controls all along the line if uniform size and quality pellets are to be produced on a definite schedule; but the goal is worth the effort—a product which can be handled like shelled corn, and which has approximately the same weight per cubic foot or bushel as shelled corn. Such a product could be stored and sold in bulk from upright concrete storage bins, eliminating the need for bags, sacks and large dried pulp warehouses.

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New Developments in Beet Top Conservation with Machine Harvest

LLOYD OLSEN[1]

Complete mechanical harvest of a dual purpose crop of sugar beets infers that both the roots and tops, which include crown, stems and leaves, are treated through the use of machinery for more complete utilization.

The physical properties of the sugar beet tops and the nature of the beet harvest have made the harvest of tops a paramount problem. Beet tops are a high moisture crop which often contact the ground after removal from the beet and are utilized during the harvest season when labor is fully engaged in the harvest of all farm crops.

Progress of the past decade in mechanical harvesting of the beet roots overshadows the progress made in mechanical harvest of beet tops but the eventual mechanization must be made of this proven feed for livestock. A sugar beet farmer is not fully mechanized for the fall harvest unless his mechanization program includes the harvest of beet tops for livestock feed.

Throughout beet growing areas, farmer-feeders value their beet tops to varying degrees and exert various methods to utilize them. The mechanical means range from a simple windrow operation through the use of a side delivery rake or windrowing attachment on the beet harvester to mechanically transporting the tops from the beet field to a storage place for curing and later use in the rations of livestock.

Many beet growers in the intermountain area follow their International harvester with a side delivery rake to windrow the tops and follow this operation with a dump rake to leave the tops fairly free of dirt and in a large pile or cock. The tops may then be pastured by livestock or ensiled. Formation of windrows or cocks helps keep the livestock from tramping the tops into the ground and also helps preserve their succulence and feed value.

A successful job of windrowing tops may be performed with a side delivery rake following most sugar beet harvesters.

The Marbeet Midget is equipped to leave the tops above the ground, free from dirt, and in a condition to enable a successful windrowing operation. This machine has a beet top conveyor belt which throws the tops to one side and out of the way of the tractor wheels and trailer cart.

Many farmers make good use of the land method and windrowing curtain of the International beet harvester. There are numerous variations using this method but the 4-row land method is typical. In working a field the harvester is started on the second row from the outside. As the tops are cut free they are picked from the topping disk by fingers and thrown to the left against the windrowing curtain. The curtain is closed while the harvester goes down this row. Reaching the end of the first row, the harvester is turned to the left and down the next row with the curtain

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[1] Livestock Consultant, Utah-Idaho Sugar Company.

still closed. Again the harvester is turned to the left to the outside row that was skipped and the curtain is opened. With another left turn at the end of the third row and with the curtain still open the fourth row is harvested and the tops from four rows are windrowed together.

The new 2-row John Deere beet harvester provides a cross conveyor whereby tops from two rows are delivered into a windrow just outside the right hand tractor wheel. This operation leaves the tops in ideal condition for later windrowing, cocking, and pick up for hauling into the feed lot.

As an aid to the International harvester, many farmers have attached a set of spiked wheels for moving the tops to one side so they are free of the tractor and harvester wheels. These wheels may be purchased or may be made by welding spikes on the rim of an old horse-drawn cultivator wheel and attached to the hydraulic control system of the tractor.

Many unique and successful systems of mechanical conservation of beet tops have been developed by farmers through the use of rebuilt and farm-built machinery. One such system is that of harvesting beets and tops with a rebuilt and converted Kiest beet harvester. The 4-row Kiest topping unit is followed by a spiked wheel side delivery rake which windrows the tops and moves them out of the way of the other equipment. Next the lifter-loader and the receiving truck remove the beets while the windrowed tops are well protected between these two units.

The top lifting and loading machine may be designed and built on the farm and under favorable conditions makes possible the saving of almost 100 percent of the tops. Pulled by a tractor, this unit picks up the tops on a rotating drum with steel prongs. The tops are thrown on a short conveyor belt which lies parallel with the rows. This belt carries the tops back to a long conveyor which runs at a right angle to the short belt. This belt in turn carries the tops to the right of the machine and into a truck that runs alongside.

If it is desired that the tops be left in the field, the arm of the top lifter may be lowered so that the tops are delivered to one side. A special trip action gate at the end of the delivery arm makes it possible for the tops to be delivered into cocks for better keeping. Hydraulic attachments are used to raise and lower the delivery arm and a similar hydraulic lift may be built under the truck bed to aid in the placement of the beet tops in the silo.

In some areas beet tops are conserved by baling, defoliating and dehydrating, and more efficient methods of handling beet tops are certain to be developed. Regardless of the method used in harvesting tops, the farmer must more fully utilize this proven livestock feed. Beet tops are excellent feed for livestock whether they are left in the fields in windrows or cocks, or hauled into the feed yard and fed as a part of the ration.

Sugar Beet Top Food Value Saved by Mechanical Methods[1]

R. D. Barmington, L. E. Jenneke, and D. M. Stevens[2]

The sugar beet plant is one of the most efficient users of the sun's energy in combining elements of the air, soil and water into useful human and animal nutrients. The lush growth of rich green beet leaves provides a storehouse for great quantities of carotene and protein. Common methods of utilizing these tops for livestock feed are very wasteful.

An analysis of the beet top shows that 45 percent of the dry matter, 85 percent of the carotene and 61 percent of the protein is contained in the leaves. After ten days in field curing 50 percent of the dry matter, 60 percent of the carotene and 50 percent of the protein are lost through mechanical handling and destruction by microorganisms, leaching, etc. This loss increases until, at the end of 40 days, 54 percent of the dry matter, 96 percent of the carotene and 63 percent of the protein are gone.

These losses have led to the establishment of a sugar beet top utilization project at the Colorado A & M Agricultural Experiment Station in cooperation with the U. S. Department of Agriculture and the Beet Sugar Development Foundation. The 1950 experiments were made possible through the cooperation of the National Alfalfa Dehydrating and Milling Company, the Great Western Sugar Company and the farmers who supplied the beet tops, Mr. Huwa and Mr. Marty.

Commercial Dehydrating Possible

Laboratory and pilot plant scale experiments prior to 1950 indicated the possibility of commercial dehydration as a means of conserving the valuable carotene and protein in beet tops. The 1950 experiments were conducted on a scale large enough to obtain data on the physical and economic feasibility of commercial application. Two methods were used to harvest the green top material in the field. The entire top including leaves, stems and crowns, the part which is normally removed during the root harvest, was obtained with an experimental John Deere two-row topper. This machine topped and loaded the tops directly into a truck or trailer, thus keeping the tops free of dirt. Earlier work suggested the desirability of dehydrating the high quality leafy material of the top separately.

This led to the development of a new machine by the mechanical engineering section of the Colorado A & M Agricultural Experiment Station cooperating with the Bureau of Plant Industry, Soils and Agricultural Engineering, division of farm machinery, USDA.

The machine, a self propelled tricycle-type, has an operating width of four rows of sugar beets. It was developed following earlier experiments with a single row type of machine. After removal of leaves, stems remain and the field appears as if hit by a violent hail storm.

Dagger-like knives, spaced two inches apart on revolving drums 15 inches in diameter, comb through the beet tops and strip off the leaves. Knives are

[1] The work on dehydration of beet tops reported herein was done under contract with the U. S. Department of Agriculture and authorized by the Research and Marketing Act. The contract is being supervised by the Western Regional Research Laboratory of the Bureau of Agricultural and Industrial Chemistry.

[2] Associate Research Engineer and Assistant Research Engineer respectively, Colorado Experiment Station, Colorado A & M College, and Associate Professor of Economics, Colorado A & M College.

one-half inch wide and two inches long. The drum turns in the opposite direction of the movement of the machine at about 300 revolutions per minute. The drums can be raised or lowered depending on the height of the beet tops. The machine operates best at about 2½ miles per hour.

Revolving action of the drums throws stripped beet leaves on a horizontal portion of the elevator belt. The elevator lifts the leaves to a truck or trailer driven along side. Normal recovery is about 70 percent of the leafy material. The remainder of the top can be utilized as pasture or ensilage.

Particle Size Reduced

It was found necessary to reduce the particle size for proper dehydration by cutting the green material as fine as possible. The whole tops and the stripped leaves were chopped in a John Deere No. 110 forage mill which had the hammers replaced by thin sharp knives and the hammer mill screen removed entirely. The auger at the bottom and the blower-elevator were also removed to prevent the fan from pulping the chopped material.

Both chopped tops and chopped leaves were dehydrated successfully in a commercial Heil alfalfa dehydrator of the National Alfalfa Dehydrating and Milling Company at Johnstown, Colorado. This machine is a triple pass, gas fired, drum drier commonly used in this area for dehydration of field crops. The capacity of the Heil drier is rated at 6,000 pounds of water evaporated per hour which determines the output of dried beet tops or alfalfa. Since the moisture content of sugar beet tops is somewhat higher than alfalfa the output of dried tops is less than alfalfa.

The relatively short season when fresh beet tops are available makes it desirable to have some means of stockpiling leaves and tops. Earlier work had indicated that this might be done by the use of silos which have the added advantage of removing some of the water without any appreciable loss of nutrients. In 1950 five temporary silos with various treatments were used as follows:

Silo No. 1, **Stripped leaves**
Not chopped
No acid treatment
Silo No. 2, **Stripped leaves**
Chopped
Two gallons of phosphoric acid per green ton of leaves
Silo No. 3, **Entire tops with crowns**
Chopped
Two gallons of phosphoric acid per green ton of tops
Silo No. 4, **Stripped leaves**
Not chopped
Two gallons of phosphoric acid and 7½ pounds of sodium propionate per green ton
Silo No. 5, **Stripped leaves**
Chopped
Two gallons of phosphoric acid and 7½ pounds of sodium propionate per green ton

Sodium propionate was added as a preservative and phosphoric acid was used to adjust the acidity for good silage quickly and to release water more rapidly. Stripped unchopped leaves were used with and without acid

treatments with the idea that the ensiling process might break down the cell structure and free the water so that chopping would not be necessary. All source materials in the chopped form dehydrated in a satisfactory manner whereas the same materials in unchopped form did not.

At Brighton, Colorado, stripped leaves were chopped and mixed with pressed beet pulp and dried in the pulp drier of the Great Western Sugar Company factory. The induced draft fan for the drier furnace produced air currents strong enough to effect a partial separation of leaves and pulp

Table 1.—Analysis of Carotene and Dry Matter in Sugar Beet Tops.

Eight treatments were dehydrated as follows: TREATMENT	Original Carotene before dehy. mg./lb. d. m. basis	Carotene after dehy. mg./lb. d. m. basis	Original dry matter % into dehydrator	Dry matter after dehy. %
1. Fresh tops and crown, chopped	38	22	17.8	91.7
2. Fresh stripped leaves, chopped	68	62	19.1	87.5
3. Fresh stripped leaves mixed with pressed beet pulp	41	9[1]	15.3	92.7
4. Silage, stripped whole leaves not chopped	71	89	15.8[2]	93.0
5. Silage, stripped leaves, chopped plus 2 gals. H_3PO_4 per green ton	68	69	20.1	94.5
6. Silage, whole tops, chopped plus 2 gals. H_3PO_4 per green ton	38	22	19.3	92.7
7. Silage, stripped leaves, not chopped, plus 2 gals. H_3PO_4 and 7½ lbs. sodium propionate per ton	82	93	17.7	91.9
8. Silage, stripped leaves, chopped plus 2 gals. H_3PO_4 and 7½ lbs. sodium propionate per green ton	82	82	18.9	93.1

[1] A rather large part of the finely chopped leaves in the mixture was dried and drawn out the top of the dehydrator by the induced draft fan rather than falling to the bottom of the drum where the rest of the leaves and pulp were taken out.

[2] Drainage was poor in this silo, making it very difficult to get an accurate sample.

Note: There is an apparent increase in carotene in some of the acid treated silages. This apparent increase also showed up in the 1949 tests.

Mowed leaves could not be obtained for inclusion in the experiment as was originally planned.

so that parts of the leaves were carried over to the cyclone separator and did not come out of the bottom of the drier where the mixture was supposed to be removed. The dried pulp and leaf mixture was a good product but not as rich in leaves as the mixture was when it entered the drier. This type of equipment could be redesigned to do a satisfactory job.

New Equipment Developed

The development of new beet harvesting equipment has opened the way to better utilization of tops. Fewer man-hours are now required to harvest an acre of beets, which allows more time for the processing of tops.

Table 1 shows the carotene and dry matter analysis of the tops both before and after dehydration. These experiments show that it is possible to retain the carotene and obtain a high quality feed by dehydration. Farmers, livestock men and feed processors are becoming increasingly aware of the potentialities of sugar beet tops for livestock feed. The economic phase of the experimental work includes data on physical inputs of labor, machinery, green tops, etc., per unit of output and dehydrated product. These inputs

Figure 1. Harvesting the entire top with a John Deere experimental two row topper.

Figure 2. Harvesting the highly nutritive leaves with the Beet Leaf Stripper.

Figure 3. Close-up showing spiked drums which comb through beet tops stripping the leaves. The drums are adjustable for height.

Figure 4. Horizontal elevator belt which catches leaves thrown back by drums.

Figure 5. Stripped and unstripped rows.

Figure 6. Chopped leaves are more easily dehydrated, and retain a high nutritive value.

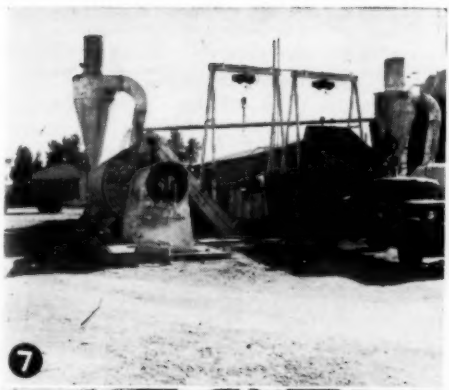

Figure 7. The type of dehydrator in which the chopped leaves and tops have been successfully dried.

Figure 8. Dehydrated sugar beet leaves.

Figure 9. Ensiling leaves may aid in removing moisture. By stock piling leaves, the normal dehydrating season could be prolonged.

Table 2.—Cost of Dehydrating Stripped Sugar Beet Leaves.

Cost of green leaves per dry ton of dehydrated material (7% moisture) calculated on the basis of $0.375 per root ton, 20 tons yield and exceptionally good tops producing .28 lbs. of leaves per foot of row			$11.00
Cost of stripping and hauling per dry ton			12.33
5 men at $1.00 per hr.	$ 5.00		
Gas and oil $0.35 per hr.	.35	1.075 tons	
Machine cost per hr.	2.66	dry material	
3 trucks at $1.75 per hr.	5.25	per hr. capacity	
	$13.26		
Cost of chopping per dry ton			2.79
2 men at $1.00 per hr.	$ 2.00		
Gas and oil $0.45 per hr.	.45	1.234 tons	
Machine per hr.	1.00	dry material	
	$ 3.45	per hr. capacity	
Milling cost—calculated by comparing with alfalfa on a moisture content basis			21.08
Cost of sacks			3.50
Total cost per dry ton (7% moisture)			$50.70

were converted into cost figures on the basis of the present price level. The tops harvested and processed by the different methods were sufficient in quantity to be representative of commercial operations.

Tables 2 and 3 show the cost of harvesting and dehydrating stripped leaves and entire tops, respectively. At the present time costs of dehydrating beet tops are high but as more tops and leaves are processed and a market for the feed is developed these production costs will be reduced.

Table 3.—Cost of Dehydrating Entire Sugar Beet Tops.

Cost of raw material on a dry ton basis (7% moisture) calculated at $1.00 per root ton and one ton of tops per ton of roots			$ 5.21
Cost of harvesting and hauling whole tops (Ave. field) per dry ton			7.73
5 men at $1.00 per hr.	$ 5.00		
3 trucks at $1.75 per hr.	5.25		
Topper cost $2.00 per hr.	2.00	1.822 tons	
Gas and oil $0.63 per hr.	.63	dry material	
Tractor cost $1.20 per hr.	1.20	per hr. capacity	
	$14.08		
Cost of Chopping			3.88
3 men at $1.00 per hr.	$ 3.00		
Gas and oil $0.45 per hr.	.45	1.148 tons	
Machine cost $1.00 per hr.	1.00	dry materials	
	$ 4.45	per hour capacity	
Milling cost—Calculated by comparing with alfalfa on a moisture content basis			23.02
Cost of sacks			3.00
Total cost per dry ton (7% moisture)			$42.84

Preliminary Experiments With Feeding Beet By-Products to Cattle

W. A. Harris and Robert H. Cotton[1]

The purposes of the present study were: 1. to compare various methods of ensiling beet tops, 2. to find how best to utilize the ensilage in cattle feeding, and 3. to compare various protein levels in a beet belt ration. The results given here are preliminary since the objectives have been only partially achieved.

Ensiling was selected as a more desirable method of preserving tops than curing because of better carotene and total nutrient recovery per acre with ensiling as compared to field curing, as shown by Wilgus, et al. (3)[2], despite a very slightly lower digestibility of the silage compared to dried beet tops (1, 2). Maynard (4) has shown that the value of tops determined in different years and places varied widely. Lionel Harris and M. A. Alexander, with lambs (5) and Folke Jarl with dairy cows (2) showed that freedom from soil was an important factor in nutritional value.

In 1949, at Swink, Colorado, seven experimental trench silos were prepared, as shown in Table 1. The tops were held in the silos approximately 100 days. For each 100 pounds of material placed into a silo, approximately 80 were recovered in all cases except silo No. 3, which had 11.9 pounds of chopped alfalfa hay for each 88.1 pounds of fresh chopped beet tops. Here

Table 1.—Silo Storage Beet Tops, Swink, Colo., 1949.

Ingredient, by Percentage	Silo Number						
	1-A	1-B	2	3	4	5	6
Chopped tops, fresh	----	86.5	81.4	88.1	80.8	----	100
Whole tops, slightly wilted	86.5	----	----	----	----	100	----
Beet seed screenings	13.5	13.5	14.8	----	----	----	----
Chopped alfalfa, low grade	----	----	----	11.9	14.3	----	----
Molasses	----	----	3.8	----	4.9	----	----
pH of finished silage	4.9	4.9	4.7	4.7	4.15	4.4	4.15
% Recovery of original weight	82.5	82.5	77.7	60.6	79.3	86.0	81.8
% Spoilage Loss	8.7	8.7	8.7	9.4	8.1	1.9	4.3

there was a recovery of only 60.6 percent. The trenches, about 30 feet long x 6 feet deep and 12 feet wide, were filled above ground level, packed by truck and tractor, and covered with sisal-kraft paper to reduce spoilage.

Various materials added to silage (Table 1) were tried in hope that material loss might thus be minimized since dry hay, etc., should act as a "blotter" to reduce drainage. Further work is needed to properly evaluate this concept.

The range in pH values in the silos when opened for feeding was 4.15 to 4.9. From the literature (2, 6, 7) it was expected that the values would be lower—close to pH 4.2. No explanation for this discrepancy is available, especially since one of the silos (No. 2 with pH 4.7) had added molasses to promote lactic acid fermentation. Nevertheless, all silages were sweet and palatable.

[1] Livestock Specialist and Director of Research, Respectively, Holly Sugar Corporation.
[2] Numbers in parentheses refer to literature cited.

Table 2.—Initial and Final Values for Storage of Beet Tops in a Silo and an Above Ground Stack.

	Days in Storage	Fresh Weight (Pounds)		Percentage Moisture		Percentage Dry Matter		Percentage Protein	
Sample		**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**
Captive 1	35	50.8	46.5	74.9	71.1	25.1	28.9	2.67	3.13
Captive 4	35	56.3	51.8	76.0	75.8	24.0	24.2	2.91	2.85
Captive 2	61	55.0	51.5	73.0	71.7	27.0	28.3	3.05	3.10
Captive 5	69	52.3	46.3	73.1	71.8	26.9	28.2	3.05	2.94
Captive 3	92	54.0	50.0	73.7	73.2	26.3	26.8	2.79	2.71
Average	58	53.7	49.2	74.1	72.7	25.9	27.3	2.9	2.9
Trench Silo	113	150,520	114,505						
Stack									
Captive 1	27	78.0	55.5	71.9	66.9	28.1	33.1	2.83	3.34
Stack	35	55,770	38,395						

Silage lost from spoilage ranged from 1.9 to 9.4 percent. It consisted of moldy material from the edge of the silo, or material rejected by steers in the feed-lot.

In 1950, at Delta, Colorado, a similar trench silo was constructed. It held 75 tons of slightly wilted, whole beet tops with a covering of 4 inches of wet beet pulp. No silage was lost due to spoilage. An above-ground stack of similar material, containing 28 tons of tops (originally, 6 feet high, 8 feet wide at the base and 20 feet long) was made at the same time. Tables Nos. 2 and 3 compare losses in the two silos. The percentage losses of moisture, dry matter and protein, shown in Table 3, were calculated from original weight times initial percentage of constituent minus final weight times final percentage.

The results are approximations since it would have been desirable to have more captive samples. Evidently, however, losses in fresh weight, dry matter and protein were much greater in the above-ground stack than they were in the trench silo, even though the tops were stored about three times as long in the trench as in the stack. Captive sample 1 was placed directly on the ground inside the trench silo and increased in dry matter and protein

Table 3.—Losses in Storage of Beet Tops in Trench Silo and Above Ground Stack.

Sample	Days in Storage	Fresh Wt. Percent Loss	Moisture Percent Loss	Dry Matter Percent Loss	Protein Percent Loss
1	35	8.4	13.0	—5.5	—7.4
4	35	8.0	8.1	7.5	10.4
2	61	6.4	8.0	1.9	4.8
5	69	11.5	13.1	7.2	14.5
3	92	7.4	8.1	5.2	9.9
Average	58	8.3	10.1	3.3	6.4
Trench Silo	113	23.9[1]			
Stack					
Captive	27	28.8	33.9	16.0	15.8
Stack	35	31.2			

[1] Trench silo had a covering of wet pulp (13.0 per cent of original weight) whose losses are included in this figure.

by drainage from above; the other captive samples were at least 1.5 feet above ground. Morton, Osland and Tom (8) reported briefly on beet top silage; losses of protein calculated from their data were 37.4 percent compared to 6.4 to 15.8 percent reported here. Jarl (2) gives a range of crude protein loss in various silages of 4.6 to 29.4 percent. The lower losses of protein were obtained in silos to which AIV acid, or formic acid, was added. With such a wide range in values further studies appear well justified.

Our estimated cost for the trench silo at Delta was $6.38 per ton of fed silage. This includes payment for tops in the field, fuel and labor at $1.20 per hour. Our haul of 5.5 miles from the field was much longer than most farmers would experience. It was estimated that under normal conditions for ensiling, both at Delta and at Swink, finished silage could be produced for $4.36 per ton. Two of our growers at Delta, W. C. Raymond and Floyd Broughton, ensiled tops for the first time in 1950. Exclusive of a charge for the tops, their costs, respectively, were $1.69 and $2.50 per ton of finished silage.

Table 4.—Rations and Gains, 2-yr.-old Fattening Steers, Jan. 17, 1950 to March 9, 1950, at Swink, Colo.

Lot No.:	13	14	16	13	14	16
Period:	21-day Adjustment Period			30-day Experimental Period		
Lot No.:	13	14	16	13	14	16
Ave. Initial Wt.	1030.9	943.3	959.9	1086.0	977.7	986.3
Ave. Final Wt.	1086.0	977.7	986.3	1155.9	1051.1	1063.5
Ave. Gain	55.1	34.4	26.4	69.9	73.4	77.2
Ave. Daily Gain	2.62	1.64	1.26	2.33	2.45	2.57
Daily Ration						
Pulp	76.37	52.41	34.46	83.11	67.33	.....
Corn	4.0	4.0	4.13	4.0	4.0	10.04
V-22 Pellets	1.33	1.33	1.33	1.33	1.33	1.91
Molasses	3.0	3.0	3.0	3.0	3.0	3.3
Alfalfa Hay	7.87	3.48	7.62	7.29	.....	4.6
Ensilage	.....	20.86	26.57	.....	28.67	37.0

Feeding Tests

The beet tops ensiled in the fall of 1949 at Swink were fed to steers at Swink from January 17 to March 9, 1950. Each pen contained 75 steers. The experiment is summarized in Table 4.

Pen No. 13 was the control; it was fed the regular commercial feed-lot ration for that year. In Pen No. 14 silage was used to completely replace alfalfa and to partially replce wet beet pulp. In Pen No. 16 part of the hay and all the wet pulp were replaced by silage. Pen No. 14 was felt to be of interest to farmers having wet beet pulp readily available; Pen No. 16 was designed for growers too far from the factory to be able to haul wet pulp. The latter ration required additional corn, it was felt, because of the difficulty experienced by the steers in the 21-day adjustment period in which their ration changed from that of Pen No. 13 to that of Pen No. 16. The V-22 pellets were 22 percent protein pellets which included vitamin and mineral supplements.

During this short study it is evident that gains in the experimental rations were poor during the 21-day adjustment period but were as good,

Table 5.—Steer Feeding Experiment, Delta, Colo., Nov. 7, 1950 to March 7, 1951.

Pen No. 2 Control, Standard Wet Pulp Ration
Average Initial Weight 755 Pounds for 40 Steers

Ration Ingredients Lbs./Head/Day	Pen No. 2 Nov. 7-Dec. 7 30 days	Dec. 7-Dec. 22 15 days	Dec. 22-Jan. 9 18 days	Jan. 9-Jan. 23 14 days	Jan. 23-Feb. 6 14 days	Feb. 6-Feb. 22 16 days	Feb. 22-Mar. 7 13 days	Average for 120 days
Green pulp	86.67	30	—	—	—	—	—	25.42
Ensiled pulp	—	60	90	90	85	85	90	62.50
Beet tailings	10	2	—	—	—	—	—	2.75
43% cottonseed cake	2	2	2	2	2	2	2	2.00
V-22 pellets	—	—	—	0.46	0.5	0.5	0.5	.23
Hay	4.67	5	5	5	5	5	5	4.92
Molasses	2.9	3	3	3	3	3	3	2.98
Nutrients:								
Dry matter	14.77	17.18	18.46	18.56	18.38	18.24	18.92	17.40
T.D.N.	10.09	12.16	13.17	13.28	13.15	13.17	13.54	12.32
Dig. Protein	1.80	1.79	1.78	1.84	1.84	1.93	2.13	1.86
Nutritive Ratio	1:4.55	1:5.8	1:6.4	1:6.22	1:6.15	1:5.82	1:5.36	1:5.62
Daily Gain								
for period	1.34	3.03	1.71	3.24	0.45	2.41	1.92	
from start	1.34	1.90	1.85	2.10	1.85	1.93	1.93	1.93
Pounds T.D.N. per 100 lbs. gain								638

or better, than the control during the last 30 days. Calculated feed costs per hundred pounds gain for the rations at Swink (using 1949-50 feed costs and $4.36 a ton for silage) were, for the adjustment period, $12.63 for the control, $18.87 for silage replacement of hay (Pen No. 14), and $27.94 for Pen No. 16, where silage replaced wet pulp. The corresponding figures in the second period were $14.47, $12.58 and $18.33.

Table 6.—Steer Feeding Experiment, Delta, Colo., Nov. 7 1950 to March 7, 1951.

Pen No. 1, Standard Wet Pulp Ration with Cottonseed Cake Replaced by "Holly" 22 Percent Protein Meal (see text for composition)
Average Initial Weight 759 Pounds for 13 Steers.

Ration Ingredients Lbs./Head/Day	Pen No. 1 Nov. 7-Dec. 7 30 days	Dec. 7-Dec. 22 15 days	Dec. 22-Jan. 9 18 days	Jan. 9-Jan. 23 14 days	Jan. 23-Feb. 6 14 days	Feb. 6-Feb. 22 16 days	Feb. 22-Mar. 7 13 days	Average for 120 days
Green pulp	86.67	30	—	—	—	—	—	25.42
Ensiled pulp	—	60	90	90	85	85	90	62.50
Beet tailings	10	2	—	—	—	—	—	2.75
43% cottonseed cake	2	0.27	—	—	—	—	—	0.53
Hay	4.67	5	5	4.64	5	5	5	4.88
Molasses	2.9	3	3	3	3	3	3	2.98
"Holly" 22%								
Prot. Meal	—	1.73	2	2	2	2	2	1.47
Barley	—	—	—	0.71	1	1	1	0.44
Nutrients:								
Dry matter	14.77	17.15	18.43	18.74	18.78	18.64	19.32	17.56
T.D.N.	10.09	11.90	12.88	13.26	13.27	13.29	13.72	12.30
Dig. Protein	1.80	1.45	1.39	1.44	1.48	1.55	1.76	1.58
Nutritive Ratio	1:4.55	1:7.2	1:8.3	1:8.21	1:8.09	1:7.57	1:6.80	1:6.78
Daily Gain								
for period	1.97	2.71	1.64	2.40	0.71	1.67	2.02	
from start	1.97	2.22	2.05	2.11	1.90	1.86	1.88	1.88
Pounds T.D.N. per 100 lbs. gain								654

Table No. 7.—Steer Feeding Experiment, Delta, Colo., Nov. 7, 1950 to March 7, 1951.

Pen No. 11, Beet Top Silage Partially Replacing Beet Pulp, Hay, and Cottonseed Meal
Average Initial Weight 745 Pounds for 40 Steers

Ration Ingredients Lbs./Head/Day	Pen No. 11 Nov. 7-Dec. 7 30 days	Dec. 7-Dec. 22 15 days	Dec. 22-Jan. 9 18 days	Jan. 9-Jan. 23 14 days	Jan. 23-Feb. 6 14 days	Feb. 6-Feb. 22 16 days	Feb. 22-Mar. 7 13 days	Average for 120 days
Green pulp	67.67	23.3	....	....	....	....	....	24.71
Ensiled pulp	—	46.7	70	70	65	67.5	80	49.64
Beet tailings	10	2	....	....	....	....	....	2.75
43% cottonseed cake	1.2	1	1	1	1	1	1.92	1.15
Molasses	2.9	3	3	3	3	3	3	2.98
Hay	3.17	3	3	1.93	2.00	3.24	4.77	3.02
Barley	....	....	....	0.71	1	1	1	0.44
Silage	21	25	25	25	25	22.19	10.38	22.12
Nutrients								
Dry Matter	18.64	18.91	19.84	19.53	19.31	19.93	20.57	19.42
T.D.N.	12.13	12.76	12.52	13.54	12.86	13.83	14.56	13.15
Dig. Protein	1.74	1.60	1.60	1.61	1.61	1.68	2.20	1.71
Nutritive Ratio	1:5.97	1:6.98	1:6.83	1:7.41	1:6.99	1:7.21	1:5.63	1:6.69
Daily Gain								
for period	1.31	2.52	1.28	2.46	1.95	1.19	2.62	
from start	1.31	1.72	1.58	1.74	1.77	1.67	1.77	1.77
Pounds T.D.N. per 100 lbs. gain								743

Silage produced at Delta was fed from November 7, 1950, to March 7, 1951. Tables Nos. 5, 6, 7, 8 and 9 summarize the rations and gains. The Delta feeding work had three objectives:

1. to study again the use of silage when wet pulp is available (Pen No. 11);
2. to study the use of silage when no wet pulp is available (Pen No. 12);
3. to study a protein level lower than that in present feed-lot practice at Delta while using a new source protein (Pen No. 1).

The new protein source, labelled "Holly 22 percent protein meal" is Table 6 for convenience, consisted of 61.6 percent dehydrated beet tops, 17.5 percent cottonseed meal, 3 percent urea, 1.7 percent linseed meal as a vitamin carrier, 13.7 percent molasses, 2.5 percent mineral supplement. We are indebted to Professor Ray Barmington of Colorado A & M for the dehydrated beet tops. The urea supplied 35 percent of the total crude protein equivalent of the "Holly 22% protein meal." Pen No. 2, Table 5, was the feed-lot control. The ration was designed to be a fast-growing rather than a strictly fattening ration.

In the protein experiment, the calculated total average daily digestible protein for Pen No. 1 ("Holly protein") was 1.58 pounds, while for the control (Pen No. 2) it was 1.86 pounds. After four months the respective gains per head per day were 1.88 and 1.93 pounds. It should be pointed out that during the first month both pens received identical rations, and then the new protein feed replaced cottonseed meal in the ration. It was felt that no significant difference existed between the two pens. It cost $14.20 per 100 pounds of gain for the control pen, and $14.09 for the lower protein pen. The 22 percent protein meal was calculated to cost $74 a ton, and the cottonseed meal cost $90.

Table 8.—Steer Feeding Experiment, Delta, Colo., Nov. 7, 1950 to March 7, 1951.

Pen No. 12, Beet Top Silage Replacing All Wet Beet Pulp, Part of Hay and Cottonseed Cake
Average Initial Weight 751 Pounds for 13 Steers

Ration Ingredients Lbs./Head/Day	Pen No. 12 Nov. 7-Dec. 7 30 days	Dec. 7-Dec. 22 15 days	Dec. 22-Jan. 9 18 days	Jan. 9-Jan. 23 14 days	Jan. 23-Feb. 6 14 days	Feb. 6-Feb. 22 16 days	Feb. 22-Mar. 7 13 days	Average for 120 days
Green pulp	10.1	—	—	—	—	—	—	2.53
Ensiled pulp	—	—	—	—	—	11.88	73.85	9.58
Beet tailings	10	2	—	—	—	—	—	2.75
43% cottonseed cake	1.23	1	1	1	1	1	1.92	1.16
Hay	3.57	3	3	1.07	1.02	2.46	4.92	2.82
Molasses	2.9	3	3	3	3	3	3	2.98
Barley	—	—	—	0.71	2.5	3.75	1.46	1.03
Silage	30.17	46	50	50	50	45.62	16.51	40.33
Nutrients:								
Dry matter	19.08	18.13	18.50	17.42	18.97	21.53	21.99	19.39
T.D.N.	11.91	11.33	11.51	11.11	12.19	14.49	15.39	12.44
Dig. Protein	1.79	1.56	1.53	1.49	1.67	1.88	2.33	1.74
Nutritive Ratio	1:5.65	1:6.26	1:6.52	1:6.46	1:6.30	1:6.71	1:5.61	1:6.15
Daily Gain								
for period	1.74	1.31	1.36	1.31	1.11	1.69	2.95	
from start	1.74	1.60	1.53	1.49	1.45	1.47	1.65	1.63
Pounds T.D.N. per 100 lbs. gain								763

Silage feeding where wet pulp was available (Pen No. 11, Table 7) was compared to the control. For four months the average daily gain was 1.77 pounds versus 1.93 pounds for the control; corresponding costs per 100-pound gain were $14.04 versus $14.20. These costs include no hauling charge for wet pulp; thus, the silage ration would be even more economical for most growers. Silage cost used in these calculations was $4.36 a ton. Morton, et al. (8) used beet top silage in a wet pulp ration containing large amounts of grain. When silage replaced 60 percent of the alfalfa gains were slightly lower but cheaper. Colorado A & M (9) in another experiment used silage to replace some of the corn and alfalfa in a high grain wet pulp ration in 1943; again gains were cheaper. They were also cheaper when extra wet pulp and silage replaced some of the alfalfa, corn and cottonseed cake. Their costs were based on $2.75 a ton for silage.

Where no beet pulp was used at Delta (Pen No. 12, Table 8) gains were slower, costs higher. For the four months the average gain was 1.63 pounds per head per day at a cost of $16.25 per hundred pounds. Even at $16.25 the profit was attractive, however. Colorado A & M work (10) on a ration containing no beet pulp but using beet top silage also showed slightly lower gains when silage was substituted for part of the alfalfa and all of the wet pulp; 1.71 pounds per head per day compared to 1.83 for the control using wet pulp. These Colorado A & M figures, based on a silage cost of $4 a ton, showed slightly cheaper gains for the silage pen.

The work at Swink and Delta indicates that possibly one should finish silage-fed steers with higher amounts of grain and alfalfa at the expense of silage for the last few weeks. Further work on this point is needed.

Feeding tests were started November 4, 1951, at Hawk Springs, Wyoming. It was felt advantageous to vary the locale for tests in order to stimulate

Table 9.—Summary of Average Daily Gains Delta Experiment, Nov. 7, 1950 to March 7, 1951.

	Average Daily Gain
Control Ration, Pen No. 2	1.93
Pen No. 1—like Control, but using "Holly" 22% Protein Meal	1.88
Pen No. 11—silage partially replacing wet pulp, hay and cottonseed cake	1.77
Pen No. 12—silage completely replacing beet pulp and part of hay and cottonseed cake	1.63

grower interest in feeding beet tops. Table 10 shows the various rations being studied. All pens were given free access to salt and a high-phosphorus mineral mix. The silage pens were fed 1/10 pound per head daily of waste factory lime in addition to the regular ration, and the urea pens were given an additional 1/10 pound per head daily of mineral mix. The objectives this year are:

1. to gain more data on use of silage with and without wet pulp;
2. to study reduction in protein level and to compare cottonseed meal with urea;
3. to compare wet pulp with dried beet pulp;
4. to observe the effect of a small amount of a high molasses pulp (Sugapulp) on a corn belt ration.

Pens Nos. 1, 5 and 9 give three levels of cottonseed cake: 1.5, 1 and 0.5 pounds, respectively. Where the cake is reduced, corn is substituted in equal amount.

Gains for the three pens for the first 92 days were 1.82 pounds, 2.12 pounds and 2.34 pounds per head per day, respectively.

Table 10.—Feeding Experiment, Hawk Springs, Wyo., Winter of 1951-1952. (Preliminary Results)

No.	Description	Pressed Beet Pulp	25% Molasses dried Beet Pulp	Chop'd Alfalfa	Gr'nd Corn	Suga-pulp	Molas-ses	Urea	43% Cotton seed Cake	Beet Top Sil-age	Pounds Gain for first 92 days
1	"Beet Belt" Control, High Protein	60[1]	—	5	6	—	3	—	1.5	—	1.82
2	Dry Beet Pulp Ration	—	9	8	8	—	1.5	—	—	—	2.15
3	Urea	60	—	5	7	—	2.8	0.2	—	—	2.35
4	Urea and Silage	60	—	2	6	—	2.8	0.2	—	15	2.23
5	Medium Protein "Beet Belt" Ration	60	—	5	6.5	—	3	—	1	—	2.12
9	Low Protein "Beet Belt" Ration	60	—	5	7	—	3	—	0.5	—	2.34
7	"Corn Belt" Control	—	—	8	15	—	—	—	1	—	1.85
6	Sugapulp in "Corn Belt" Ration	—	—	8	13	2	—	—	1	—	2.42
8	Beet Top Silage in "Corn Belt"	—	—	5	14	—	—	—	—	25	1.47

[1] Ration figures in pounds fed per head per day.

Pen No. 2, with the dry pulp ration, showed an average daily gain of 2.15 pounds per head.

Urea was fed in Pens Nos. 3 and 4 at Hawk Springs. Pen No. 3 differs from the control in that 0.2 pound of urea replaces an equal weight of molasses and one pound of corn is used in place of 1.5 pounds of cottonseed cake. Pen No. 4, urea plus silage, differs from Pen No. 3 in that 15 pounds of silage replace 3 pounds alfalfa plus 1 pound of corn. The gain for pen No. 3 was 2.35 pounds per head per day for the 92 days. And in the urea, plus silage, Pen, No. 4, the average daily gain was 2.23 pounds.

The "corn belt" rations are designed for growers who cannot economically obtain pulp. Pen No. 7 is the control (11); Pen No. 8 uses 25 pounds of beet top silage to replace one pound of corn and three pounds of hay. Pen No. 6 differs from control Pen No. 7 by substitution of two pounds of high-molasses pulp (Sugapulp, 80 percent liquid molasses equivalent) for two pounds of corn. The average daily gain for the control, Pen. No. 7, was 1.85 pounds per head per day for the 92 days. The silage pen, No. 8, showed a weak 1.47 pounds per head per day gain. Pen No. 6 has given an average daily gain of 2.42 pounds.

Summary

1. Fresh and slightly wilted beet tops were stored in tightly packed trench silos at Swink, with and without additions of other preservatives, and covered with sisalkraft paper. Weight losses ranged from 14 percent for whole, slightly wilted tops to 39.4 percent for fresh chopped tops in alternate layers with chopped alfalfa. Spoilage losses ranged from 1.9 percent to 9.4 percent on the same two silos.

2. Slightly wilted tops in a tightly packed silo at Delta, were covered with wet beet pulp. No spoilage occurred. Fresh weight loss was 23.9 percent, including the wet pulp covering. Captive samples within the silo indicated less weight loss for the tops alone, 8.3 percent. Dry matter and moisture losses averaged 3.3 percent and 10.1 percent, respectively. Protein losses averaged 6.4 percent.

3. Wilted tops, stacked above ground, showed 31.2 percent weight loss. The one captive sample in the stack showed a weight loss of 28.8 percent. Dry matter loss of 16.0 percent and protein loss of 15.8 percent was indicated by the captive sample.

4. By mechanical handling, silage was produced at Delta, Colorado, at a cost of $6.38 per ton. It was estimated that a similar operation with normal hauling distance and proper equipment available would have allowed silage to be produced at $4.36 per ton.

5. Beet top silage was fed to steers in rations with and without wet pulp. Gains were slightly slower, but more economical when silage replaced part of the wet pulp and part, or all, of the alfalfa in the ration. Where all wet pulp was replaced by silage, slower and more expensive gains resulted.

6. Dehydrated beet tops were used as the main bulk of a 22 percent protein meal in which 35 percent of the protein equivalent was supplied by

urea. The meal was used to replace 43 percent cottonseed meal, pound for pound in a "beet belt" ration.

7. At present, feeding trials are under way to compare the effect of feeding different protein levels in a "beet belt" ration; to further study the place of urea and of beet top silage in a "beet belt" ration; to determine the efficiency of beet top silage in a "corn belt" ration to find whether Sugapulp, a dry feed of high molasses content, is beneficial in a "corn belt" ration, and to determine the economy of a dry pulp versus a wet pulp ration.

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The Value of the Beet Top Crop

H. M. Bauserman and C. W. Doxtator[1]

The sugar beet crop has always been two crops in one: the beet root for sugar extraction, and the tops and crowns for stock feed. Changing farming methods and practices call for constant re-evaluations. Changes in harvesting methods: mechanical harvesters, beater toppers and laxity of hand labor in topping beets, have resulted in a tendency by the beet grower to deliver to the factory more and more crown with the beet root. Improperly topped beets have been accepted since there is an awareness of the harvesting problems.

The worth of the beet root and crown has not been clearly evaluated for present day factory and feeding operations. A. W. Skuderna, vice president and general agriculturist for the American Crystal Sugar Company, suggested that such study would be worthwhile and, accordingly, tests were conducted at several factories of the Company.

It is the purpose of this paper to present and evaluate data on roots and crowns for percent sucrose, juice purity and percent extraction sucrose, along with present monetary value. The data presented was obtained during the 1951 harvest season from six of the eleven growing areas of the American Crystal Sugar Company.

Methods

Freshly harvested beets were taken to the nearest factory laboratory and divided into samples of 10 or 15 beets. The petioles were cut from the crowns, and the crowns cut from the root at the lowest leaf scar as prescribed by standard tare instructions. The weight of the crown and root portion was then recorded. Pulp was obtained from the roots by rasp or Spreckles saw. The entire crown portion was reduced to a finely chopped mass using a Buffalo chopper. Sodium and potassium were measured using the flame spectrophotometer. Sugar was determined by the Sachs-Le Docte method and direct polarization. Purity determinations were made on a hot water digest of the pulps using a refractometer for Brix measurements. The other reported data were obtained by application of the 13 equations listed.

1. Weight of the part percent of the total weight of the plant = (b)

$$(b_r) = \frac{(a_r) \times 100}{(a_r) + (a_c)}$$

$$(b_c) = \frac{(a_c) \times 100}{(a_r) + (a_c)}$$

Subscripts r and c used in the equations denote the data refers to roots or crowns, respectively.

2. Extractable sugar percent on sugar present = (e)

$$(e) = \frac{\left(190. - \frac{9{,}000}{P}\right)\left(S - .60\right)}{S}$$

Where P = purity of beet material
S = sugar content of beet material
assumes a standard factory condition of

1. Total sugar losses of 0.60 percent on beets
2. Beet end non sugar elimination 40 percent
3. Purity of final molasses 60.

[1] Experimental Chemist and Plant Breeder, respectively, American Crystal Sugar Company, Rocky Ford, Colorado.

3. Extractable sugar in the part % of weight of part = (f)
   (f) = (c) × (e)
4. Extractable sugar in the part % on weight of total plant = (g)
   (g) = (b) × (f)
5. Extractable sugar in the part % on total extractable in the plant = (h)
   $(h_c) = (g_c) \times 100/[(g_c) + (g_r)]$
   $(h_r) = (g_r) \times 100/[(g_c) + (g_r)]$
6. Total payment per ton basis sugar content, dollars = (k)
   (k) was found by using a factory contract used recently.
7. Per ton extraction value of the crowns, based on extractable sugar in the crowns, dollars = (m)
   $(m_c) = \frac{(e_c) \times (k_c)}{(e_r)}$
   $(m_r) = (k_r)$
8. Difference between payment basis contract and the extractable sugar value per ton of crowns = (n)
   $(n_c) = (k_c) - (m_c)$
9. Weight of the crowns % of the weight of the roots = (p)
   $(p) = \frac{(a_c) \times 100}{(a_r)}$
10. Contract value of the crowns from one ton of roots based on extractable sugar in the roots and crowns, dollars = (r)
    (r) = (m) × (p)
11. Yield of dry tops % on roots = (s)
    (s) = 50% of weight of fresh crowns
12. Value of dry tops from one ton of roots = (t)
    $(t) = \frac{(s) \times \$24.40}{100}$
13. Difference between the sugar value aand the feed value of tops per ton of beets = (u)
    (u) = (t) — (r)

Experimental Results

We wish to find the relative value of the tops and roots. This indicates to us the ultimate use to which the top portion of the crop should be put and should be based on three factors: 1. the extractable sugar in the parts, 2. the beet contract price value and 3. the stock feed value.

The data in Table 1 indicate that different varieties, locations, growing conditions and maturity of the crop affect the composition and weight of both crown and root. The many variations are apparent in the data; nevertheless, it will be seen that the relative composition of the roots and crowns is constant in one direction. By including several varieties from many areas, generalized conclusions can be reached.

In Table 2 is found the experimentally determined qualities of the samples and the calculated factor, the extractable sugar in the part, percent of total extractable in the plant. In all cases the amount of extractable sugar contained in the crown is a small percentage of the total extractable in the plant. It is general knowledge that, the higher the topping, the poorer is the quality of juice obtained from the crown.

Table 3 is presented to show the difference between the contract payment value and the extractable sugar value per ton of crowns. Even though

Table 1.

Part	Weight	% Sugar	Purity	% Na	% K
Average of Rocky Ford test, Variety 0-410, 60 Beets Tested					
Root	1.26	14.25	90.54	.082	.158
Crown	.33	4.53	79.16	.134	.153
Difference		9.72	11.38	—.052	.005
Average of Rocky Ford test, Variety 3N, 60 Beets Tested					
Root	1.31	13.65	88.59	.164	.153
Crown	.32	4.33	74.71	.193	.135
Difference		9.32	13.88	—.029	.018
Average of Texas test, Variety US 22, 60 Beets Tested					
Root	1.99	15.52	92.87	.016	.281
Crown	.45	5.08	85.74	.025	.221
Difference		10.44	7.13	—.009	.060

this particular contract may not be in use at present, the same relative values would hold and comparisons are valid. One can conclude that the contract price for crowns is not a fair basis of payment since the crowns contain a poorer quality of juice and hence there is an overpayment to the grower which ranges from $.65 to $2.27 per ton of crowns.

The fact that the crowns are not valuable for sugar making purposes might be unfortunate if it were not for the fact that the crowns have another value which is greater than their sugar-making value. When applied in feeding operations it is found that the value of the crowns is a very real one that will net the farmer a very good return. Table 4 shows the value obtainable by the feeding of tops. The replacement value of tops per ton of beets of $24.40 was obtained by using Maynard's (1)[2] replacement values of 322 pounds of corn and 1,050 pounds of alfalfa hay. The market value

Table 3.

Test Area and Varieties		Parts of the Plant	Total Payment per ton Basis sugar content, dollars	Per ton Extraction value of part, basis extractable sugar in the part, dollars	Difference between payment and value of ton of crowns
			(k)	(m)	(n)
Clarksburg	US No. 33	Root	14.22	14.22	
Clarksburg	US No. 33	Crown	9.82	7.72	2.10
Rocky Ford	Am. 3 N	Root	11.72	11.72	
Rocky Ford	Am. 3 N	Crown	3.34	2.37	.97
Rocky Ford	Am. 1—0410	Root	12.24	12.24	
Rocky Ford	Am. 1—0410	Crown	3.53	2.69	.84
Texas	US No. 22	Root	13.39	13.39	
Texas	US No. 22	Crown	4.02	3.37	.65
Chaska	Am. 3LSR	Root	14.76	14.76	
Chaska	Am. 3LSR	Crown	11.46	9.95	1.51
E.G.F.	Am. 3N	Root	13.00	13.00	
E.G.F.	Am. 3N	Crown	11.04	8.77	2.27
Mason City	Am. 3LSR	Root	15.22	15.22	
Mason City	Am. 3LSR	Crown	12.64	11.42	1.22
Mason City	US 216—47501	Root	15.30	15.30	
Mason City	US 216—47501	Crown	13.10	11.88	1.22

[2] Numbers in parentheses refer to literature cited.

Table 2.

Test Area and Varieties		Part of the Plant	Avg. Wt. of Part	Wt. of part % of Total	% Sugar of Part	Purity of part (Refractometer)	Extractable sugar in part % on sugar present	Extractable sugar in part % on weight of part	Extractable sugar in part % on weight of total plant	Extractable in part % of total extractable in the plant
			(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Clksburg	US No. 33	Roots	2.91	92.7	16.51	87.85	84.37	13.93	12.91	95.84
Clksburg	US No. 33	Crowns	.23	7.3	11.54	75.00	66.36	7.66	.56	4.16
R. Ford	Am. No. 3 N	Roots	1.31	80.4	13.65	88.59	84.52	11.54	9.28	94.79
R. Ford	Am. No. 3 N	Crowns	.32	19.6	4.33	74.71	59.90	2.59	.51	5.21
R. Ford	Am. No. 1—0410	Roots	1.26	79.2	14.25	90.54	86.78	12.37	9.80	94.05
R. Ford	Am. No. 1—0410	Crowns	.33	20.8	4.53	79.16	66.20	3.00	.62	5.95
Texas	US No. 22	Roots	1.99	81.6	15.52	92.87	89.49	13.89	11.33	94.18
Texas	US No. 22	Crowns	.45	18.4	5.08	85.74	74.99	3.81	.70	5.82
Chaska	Am. No. 3 LSR	Roots	1.58	84.0	17.03	89.10	85.86	14.62	12.28	88.54
Chaska	Am. No. 3 LSR	Crowns	.30	16.0	13.36	80.40	74.55	9.96	1.59	11.46
E.G.F.	Am. No. 3 N	Roots	.99	72.3	15.09	87.15	83.28	12.57	9.09	79.32
E.G.F.	Am. No. 3 N	Crowns	.38	27.7	12.94	74.60	66.14	8.56	2.37	20.68
M. City	Am. No. 3 LSR	Roots		Est. 80.0	17.50	91.50	88.50	15.49	12.39	84.06
M. City	Am. No. 3 LSR	Crowns		Est. 20.0	14.70	84.40	79.96	11.75	2.35	15.94
M. City	US No. 216—47501	Roots		Est. 80.0	17.60	91.40	88.41	15.56	12.45	83.61
M. City	US No. 216—47501	Crowns		Est. 20.0	15.20	84.50	80.19	12.19	2.44	16.39

Table 4.

Test Area and Varieties		Part of the Plant	Wt. of fresh crowns % of the wt. of roots	Value of parts from 1 T. roots, basis extractable sugar	Yield of tops % on roots, (50% fresh crowns)	Value of tops from 1 T. roots $24.40 per ton	Difference between sugar value and feed value of tops from 1 T. of beets
			(p)	(r)	(s)	(t)	(u)
Clarksburg	US No. 33	Root		14.22			
Clarksburg	US No. 33	Crown	7.90	.61	3.95	.96	.35
Rocky Ford	Am. 3 N	Root		11.72			
Rocky Ford	Am. 3 N	Crown	24.43	.58	12.22	2.98	2.40
Rocky Ford	Am. 1—0410	Root		12.24			
Rocky Ford	Am. 1—0410	Crown	26.19	.70	13.10	3.20	2.50
Texas	US No. 22	Root		13.39			
Texas	US No. 22	Crown	22.61	.76	11.31	2.76	2.00
Chaska	Am. 3LSR	Root		14.76			
Chaska	Am. 3LSR	Crown	18.99	1.89	9.50	2.32	.43
E.G.F.	Am. 3N	Root		13.00			
E.G.F.	Am. 3N	Crown	38.38	3.37	19.19	4.68	1.31
Mason City	Am. 3LSR	Root		15.22			
Mason City	Am. 3LSR	Crown	25.00	2.86	12.50	3.05	.19
Mason City	US 216—47501	Root		15.30			
Mason City	US 216—47501	Crown	25.00	2.97	12.50	3.05	.08

of corn was taken to be $3.50 per cwt. and the alfalfa hay $25.00 per ton. As the table shows, the feeder will obtain an additional revenue per ton of beets, ranging from $4.68 to $.96 without including any manure value. Moreover, the feed value is $.08 to $2.50 more than the sugar making value. Feed prices will fluctuate with areas and times. In the few instances where we worked through the data using corn and hay prices for other specific areas, it was found there were even greater differences in favor of feeding the tops.

This study was made because it is important that the farmer be provided with information which will make his operations as economically sound and profitable as possible.

Conclusions

The data presented here were drawn from across a wide area and thus the general situation for the entire western United States can be summarized in the following conclusions:

1. There are only relatively small quantities of extractable sugar in the crown.

2. The contract price basis is not a fair means for determining the value of the crowns.

3. Even though no manure values are credited to a feeding operation, the feed value of the tops is a significant portion of the total value of the beet crop and the tops should be thus used for the greatest advantage to the beet grower.

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GENETICS
AND
VARIETY IMPROVEMENT

A Comparison Between Corn and Sugar Beet Breeding Methods

RUSSELL T. JOHNSON[1]

The exact origin of corn is lost in antiquity but its value as a food was recognized and exploited by many of the primitive people of South and Central America. The sculptures depicting corn plants found in the remains of Mayan, Inca and Aztec villages are evidence of the dominant part corn played in those ancient civilizations.

It is probable that those people exercised some selection with corn because by the time Columbus discovered the New World the natives were cultivating five distinct types. These types were dent, flint, flour, sweet and pop corn; not greatly different from those same types we grow today. Their method of propagation was, in all probability, the saving of good ears each year as a seed supply for the following year. Some of these peoples made a practice of planting seeds of different colors in each hill. Their purpose of doing so is not known, but in effect it may have helped maintain heterozygosity and prevent reduction in vigor through inbreeding.

The variability in corn made it readily adaptable to a wide variety of climatic conditions so that its culture spread from the tropics of Central and South America to the temperate regions of North America. The Pilgrims, upon landing in Massachussetts in 1620 found the Indians there cultivating corn. As settlement moved westward in this country corn was, from the beginning, one of the major agricultural crops. Until the early part of the present century the predominant breeding methods used with corn consisted of selecting ears of a desired type from healthy plants in the field at harvest time and using these as seed for the subsequent crop. This method is called mass selection and is essentially the same as had been used by the Indians for centuries. It is doubtful if it resulted in any particular genetic improvement of the crop beyond adaptation to particular environments and possibly some disease resistance.

In contrast to corn, the origin of the sugar beet, as it exists at present, is known and the steps in its development are quite accurately recorded as reviewed by Coons (4)[2]. Marggraf first produced crystal sugar from *Beta rubra* and *Beta alba* in 1747, but it was his pupil, Achard, who developed the agricultural and processing methods to initiate the beet sugar industry. Achard began his experiments with beets as a source of sugar in 1784 and from the "Runkelruben," a near relative of the mangel-wurtzel, he carried on a selection program which produced the White Silesian beet. His selection methods included the evaluation of purity and sucrose content of the roots in addition to visible characteristics of the beet plants.

In 1856, Vilmorin, of the French seed firm of the same name, while working with sugar beets developed a breeding principle which stands as one of the earliest and still most fundamental principles of the science of plant breeding. He found that the breeding value of an individual was not dependent upon the excellence of that particular individual but upon its

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[1] Plant Breeder, Spreckels Sugar Company, Spreckels, California.
[2] Numbers in parentheses refer to literature cited.

ability to transmit desirable characteristics to its offspring. The demonstration of this principle is commonly called the progeny test and is the basis for all breeding programs on crops which are propagated through seed. By use of this principle together with newer and more rapid methods of selection for sucrose content of the root, Vilmorin developed strains which, in yield and sucrose content, were probably similar to the varieties which are grown at present.

As pointed out before, mass selection had little effect in the genetic improvement of the corn crop. In fact, when selection is very rigid for a particular character, there is often a reduction in the yield of the crop. This is apparently due to the limitation placed on the genetic diversity of the progeny by a close selection for a particular type. Hayes and Alexander (8) showed this in selecting for certain ear types in corn. Winter (28) reported the results of twenty-eight years of selection for oil and protein content of corn. Although no yield data are given, it seems reasonable to assume that a reduction in vigor accompanied the rigid selections for oil and protein because the experiment was modified twice to prevent too close inbreeding. This same situation is found in sugar beets. In selecting for high sucrose content of the beets a reduction in root weight of the progeny is often observed.

In 1899, Hopkins, at Illinois, initiated in his corn breeding program a type of progency test which was called *ear-to-row* selection. This consisted of planting a row of corn from each ear selected the previous year, and continued selection within the better yielding rows. Modifications of this method included detasseling part of the rows to prevent too close inbreeding, and saving remnants from each ear so composites could be made of the higher yielding selections. Some early reports indicated that some progress was made by using this method, but later reports (24) demonstrated that it had been of little value in increasing yields.

This method had two basic weaknesses. The field plot techniques used were not precise enough to correctly evaluate the material and those lines which were inherently high-yielding were a mixture of complex hybrids which could not be duplicated. A method very similar to this and commonly called "family breeding" has been used in sugar beet breeding also, and some results are discussed by Brewbaker and McGreevy (2). Although sound field plot techniques were apparently used, only slight, if any, improvement other than adaptation could be attributed to this method when lines were maintained without controlled pollination.

About 1905 East, at the Connecticut station, and Shull, at Cold Spring Harbor, began studying the effects of inbreeding and cross breeding corn. In 1908 Shull suggested the use of F_1 crosses between inbreds, but this method was never used much because of the high cost of seed due to the low seed yields produced on weak inbreds. In 1909 East suggested the more practical method of hybridization in corn, making crosses between varieties without inbreeding. This method had been suggested earlier by Beal at Michigan in 1880, but had apparently not been used. Varietal hybridization was carried on to a very limited extent from 1909 to about 1920.

Jones (16) in 1918 suggested the possibility of the use of double cross seed for the commercial crop. This eliminated seed cost as a prohibitive element because seed for the commercial crop would be produced on vigorous single cross plants and per acre seed yields would be high. Interest was renewed in inbreeding and subsequent crossing of lines. With an economically sound method of utilizing hybrid vigor available, two problems faced the corn breeder: 1. the production of desirable inbred lines, and 2. the most advantageous use of these lines in hybrid combinations.

As a result of the increased interest and research conducted with corn, an ever increasing fund of information has been contributing to a better understanding of the principles and methods involved in developing better corn hybrids.

Richey and Mayer (22) in 1925 found no difference in yield of single crosses between inbred lines selfed three and five generations. Davis (6) in 1927 first used the inbred-variety or top-cross as a method of determining combining ability. Jenkins and Brunson (14) in 1932 showed a comparison of the top-cross performance with the average performance of the single crosses involving a particular inbred as a method of evaluating combining ability of inbred lines. They showed relatively high correlation between yields of inbred-variety crosses and the average performance of a line in single crosses.

The importance of producing hybrids from unrelated inbreds (genetic diversity) has been pointed out by several (5) (9) (15). In general these experiments have shown that hybrids produced from unrelated inbreds have consistently yielded more than hybrids whose parental inbreds were related. The importance of genetic diversity in sugar beet breeding has been pointed out by Brewbaker, et al (1).

That combining ability is a heritable character in corn has been demonstrated by Johnson and Hayes (15) and Cowan (5). Lines selected from the progenies of single crosses whose component inbred parents were low combiners produced significantly lower yielding single crosses than lines derived from single crosses made from two high combining lines or one high and one low combining line.

Jenkins (12) has developed a method by which the yield of double crosses can be predicted from the performance of single crosses. From four inbred lines, six different single crosses can be made and three different double crosses utilizing all four inbreds. Of four methods tested, Jenkins found the correlation between predicted and actual yields of double cross hybrids to be highest when using the average yield of the four non-parental single crosses as the predicted value.

Based on this increasing supply of information, a more or less generally accepted method of producing corn hybrids evolved. It consisted of selecting and self-pollinating outstanding individuals from an open-pollinated variety. Progeny rows were grown from this selfed seed the following year and the best plants from the more promising rows were selected for further self pollination. This process continued for three to five generations at which time the remaining selected lines were crossed to a tester

variety to determine the average or general combining ability of each line. Based on the performance of this top cross seed, the best lines were tested in specific single cross combinations. From the results of the single cross trials, double cross yields were predicted and the most promising combinations were made. These double cross hybrids were then grown in comparison with standard varieties to determine what progress had been made.

As desirable inbred lines became available, planned crosses between two such inbreds became a valuable source for isolating new inbreds. This method of obtaining inbreds from planned crosses is probably the greatest source of inbred lines of corn at the present time.

During the time the corn breeders were making such rapid strides in the development of corn hybrids, sugar beet breeders were faced with the problem of developing a sugar beet variety which would withstand the ravages of certain disease conditions. In most of the sugar-beet-growing areas west of the Rocky Mountains, an insect-borne virus which caused a disease known as beet blight or curlytop threatened the survival of the entire sugar beet industry. Many beet sugar factories were abandoned because of successive crop failures due to this single disease.

In 1934 the first so-called curly-top-resistant variety, U. S. 1, developed by the U. S. Department of Agriculture, was made commercially available. By present-day standards, the resistance possessed by this variety was only slight, but it represented the first of a series of improvements which have led to the highly resistant variety, U. S. 22, and its derivatives.

These varieties have made possible the growing of a successful crop of sugar beets in areas which had previouly been abandoned for sugar beet culture, and stand as a tribute to those individuals who took part in their development. These varieties have been produced largely by mass selection and although they will produce a satisfactory crop under severe disease conditions, numerous tests have shown that in the absence of disease their performance is about equal to the European varieties from which they were derived. This is additional evidence that mass selection is of little value in increasing the inherent yielding ability in an adapted variety.

In many areas east of the Rocky Mountains a leaf spot disease caused by the fungus, *Cercospora beticola*, caused considerable damage, particularly in reducing the sucrose content of the beets in certain years. Mass selection had not been effective in developing any resistance to this organism. The first source of resistent material appeared in fourteen of some two hundred strains of beets which had been selected on the basis of certain morphological characteristics. Those strains showing some resistance were inbred in an attempt to obtain some lines homozygous for resistance. Later, five of the best lines were combined to form the synthetic variety, U. S. 17, which was introduced in 1937. Continued improvement has led to the variety U. S. 215 x 216 which is presently grown on considerable acreage in areas subject to leaf spot epidemics. This variety, however, in a year without serious leaf spot conditions, performed no better, if as well, than a composite of European varieties. This is not surprising even in view of the fact that this variety was produced from somewhat inbred lines. The lines were selected on the basis of disease resistance and probably represented random lines

with regard to combining ability. Another reason may be that, if the lines were self-fertile enough to be maintained as inbreds by self pollination, considerable self-pollination in the seed fields may account for some reduction in vigor.

With the major disease problems in sugar beets somewhat alleviated, the attention of plant breeders was turned more to the commercial utilization of hybrid vigor. Some investigators demonstrated experimentally that hybrid vigor was apparent in some crosses between varieties and between inbreds of sugar beets (7) (27). In general, the hybrid vigor expressed has been in the form of increased root weight rather than increased sucrose percentage. The commercial exploitation of this phenomenon, however, encountered difficulty from the start. Most selected individual beets could not produce self-pollinated seed due to an inherent condition of self sterility (17). This precluded the possibility of developing inbred lines from all selected individuals. Some individuals, however, would produce some self-pollinated seed. A few individuals were found to be rather highly self fertile. From these self-fertile beets, inbred lines could be produced but the utilization of the inbreds was difficult.

Unlike the monoecious corn flower in which the male and female portions of the flowers are widely separated and easily emasculated, the sugar beet has a perfect flower in which the male and female portions are adjacent to each other. To insure cross fertilization in self fertile strains of hermaphoditic beets each flower on the plant or branch to be used as the seed parent of the cross must be hand emasculated. While this practice is satisfactory to produce small experimental lots of seed, it is obviously not practical on a commercial scale.

Recently, Owen (18) reported the finding of a type of male sterility in sugar beets which was dependent for its expression upon both cytoplasmic and genetic factors. A male sterile plant produces no viable pollen and, therefore, can function only as a female or seed parent. This discovery has opened a way by which it now seems possible that inbred lines of sugar beets may be developed and utilized to produce superior hybrid varieties. To main completely male sterile lines, however, pollen must be supplied to them from an hermaphroditic line so genetically constituted that, when crossed to a male sterile, all offspring are also male sterile. Such hermaphroditic lines have been called "O" types and the genotypes of these lines are described by Owen. They apparently occur with varying frequency in most open-pollinated populations. Therefore, for each male sterile line maintained, a specific pollen-producing line must be also maintained in order to insure a continued supply of completely male sterile plants each generation. At the present time there is a considerable effort being put forth by sugar beet breeders in the search for genotypes of "O" type beets.

In self fertile material, by self-pollinating the "O" types and at the same time backcrossing them to male sterile strains in each of several generations, two inbreds are developed which approach being genetic equivalents except that one is an hermaphrodite, and, due to the cytoplasm of the other, it is male sterile. In self sterile material, the "O" types and their developed male sterile equivalents will represent a much more heterogeneous popula-

tion than in the case of the self fertile material. Self-sterile type "O" plants will be isolated from paired crosses or clones because they cannot be self pollinated. It seems possible that such male steriles may be of value as a tester for combining ability of inbred lines because of the broader genetic base they would possess, but their value seems doubtful in a long range program for use in commercial hybrids.

Some male-sterile hybrid varieties of sugar beets are now being produced on a limited scale. These hybrids fall into two types: those which are made using male-sterile equivalents of self fertile inbred lines, and those using male-sterile strains of relatively self-sterile material. Hybrids made from self-fertile material utilize complete male sterility or are rogued very carefully in the seed field to prevent pollen shedding from any plants of the seed parent. This procedure is necessary because a small amount of self-pollinated seed could easily nullify the desirability of the seed which was true hybrid. In those hybrids using relatively self sterile material, while complete male sterility would be highly desirable, partially or "semi" male sterile plants which shed some pollen would not be as deleterious as with self fertile inbreds because the resultant seed would be a mixture of hybrid and the female parent. Very little actual self pollination would occur under such circumstances. Such a hybrid would represent the average combining ability of each population in combination with the other. While such hybrid may be an improvement over present open-pollinated varieties, it seems possible that lines of higher than average combining ability could be isolated from each population. It would seem that, in the long range program, hybrids from inbreds offers more promise than hybrids between the more heterogeneous populations of relatively self-sterile material.

Some of the main points in the commercial production of hybrid sugar beets are still to be worked out. It is quite possible that the production of single cross hybrids, as was found with corn, may not be economically feasible. The commercial seed crop would have to be produced on inbreds and the seed yield may be so low that the cost would be too high to be practical. Owen (19) has suggested the use of three-way crosses which might be represented as (A x B) x C. In this case, inbred "A" would have to be a male sterile line. Inbred "B" would have to be of type "O" so the single cross on which the commercial seed crop was to be harvested would be male sterile. Inbred "C" could be any high combining line. Its genotype regarding male sterility would be immaterial because the commercial portion of the sugar beets is the vegetative part of the plant. This appears to be a satisfactory type of cross if the pollen inbred used in the final cross will produce sufficient pollen to provide adequate seed setting. Such a cross would require the maintenance of a minimum of four inbred lines; B, C and both the male sterile and hermaphroditic phases of line "A." In actual practice the two phases of an inbred line will be maintained in the same isolation whether it be by space or bagging. Separation will be maintained in the planting and harvesting of them. A minimum of six lines would be required to produce a double cross hybrid comparable to the corn hybrids used.

The problem of preliminary testing for combining ability is also not completely solved. For those inbred lines on which both the male sterile

and male fertile equivalents are being produced, the testing can probably closely parallel the testing of corn. An adapted variety of beets with a broad genetic base to be used as the tester parent can be interplanted between the rows of male sterile lines. All pollen in the field then should come from the tester parent and seed harvested from the various lines in such a plot would be top-crossed seed.

Performance trials conducted with seed harvested from each line should give an adequate test of general combining ability. Although such a test would be made only on the male sterile equivalent phase of each line, the results should be indicative of the combining ability of the male fertile phase also, provided such test was not made in the early back-cross generations. It is obvious that tests made on the male sterile phases early in the back-crossing program would not reflect the combining ability of the hermaphroditic phase which would be the recurrent parent of the backcross. The only exception to this would be the case in which the same male sterile inbred was used to initiate the development of the male sterile equivalents for all hermaphroditic lines to be tested in any given test. In this event, such a test would be similar to a breeding method called "gamete selection" in corn (26), which is discussed later in this paper.

In the process of developing inbreds, many of the strains will be found to neither be nor segregate for the type "O" genotype and, consequently, their male sterile equivalents cannot be readily developed. Bcause a considerable portion of the genotype of each hybrid will be contributed from inbreds which need not necessarily be type "O," it does not seem to be a sound practice to discard these if they are highly desirable otherwise. The evaluation of general combining ability of these lines will probably present a problem. Top-cross tests as described above would be unsatisfactory because each of these lines would produce pollen and, being self fertile, probably ten percent or less of the seed produced would be crossed seed. Hand emasculation to insure crossing would be so time-consuming as to make it impractical. A male-sterile strain, preferably not an inbred, might be used as a tester, but this method would require bagging or a separate space isolation for each line to be tested. As the number of lines to be tested increased, the problem of providing satisfactory space isolations would become progressively more difficult. Another possibility for evaluating a group of such lines would be to conduct comparative tests on the inbreds themselves, after careful selection for disease resistance and other observable characteristics.

Disease resistance, because of its extreme importance in sugar beet breeding, may make possible a much more rigid selection of lines in sugar beets than is possible with many other crops.

In the continuing attempt to find more efficient methods of developing new corn inbreds, several breeding methods have been suggested. Some of these have been accepted as sound breeding practices and others have been the subject of much controversy. A few of them are mentioned very briefly here because they may have some possibility of use in a sugar beet breeding program with some modifications.

Jenkins (13) presented some data from top-crosses made after successive generations of inbreeding from which he concluded that the combining ability of a line becomes fixed relatively early in the inbreeding program and it maintains that level quite constant through the succeeding generations. This principle has become known as early testing and has received considerable support from Sprague (25).

As practiced at Iowa, early testing involves the outcrossing to a tester at the same time as the first selfing, selecting only 10-15 percent of the selfs on the basis of the top-cross yield trial, for carrying on in the inbreeding program, and top-crossing again in S_4 for the final evaluation of general combining ability. Early testing has met considerable criticism from several corn breeders. Richey (20), in a reanalysis of Jenkin's data, points out that the families did change relative positions with regard to combining ability prior to S_4, but that Jenkin's conclusions were based on successful selections in S_4 and the fact that the combining ability of the families remained constant after that. From Sprague's data Richey maintains that only fifteen percent of the material could be discarded on the basis of early testing without discarding desirable parental material. Singleton and Nelson (23) presented data from early testing of sweet corn and concluded that the method is not genetically sound before S_3, and, even if sound, would be of doubtful value on the basis of expense involved. Both early and late testing are still being practiced.

Stadler (26) has suggested a method called gamete selection. It consists of crossing gametes from a selected source with an inbred of known performance, selfing as many of the resulting plants as there are gametes to be tested, and at the same time outcrossing to a suitable tester. For comparison the inbred is also crossed onto the tester. Any increase of (gamete x inbred) x tester over inbred x tester is assumed to be due to the gamete. Therefore, the selfed seed from the high yielding gamete x inbred top crosses should be a good source of further inbreeding and selection. This method assumes early testing to be a valid corn breeding principle. Stadler states the advantages of this method are: 1. increased frequency of exceptional zygotes, 2. gamete x inbred crosses will be at least heterozygous for all desirable agronomic characters possessed by the inbred, and 3. further possibilities of improvement by selection in superior gamete x inbred crosses. Hayes, Rinke and Tsiang (10) have questioned the necessity for the gamete x inbred top crosses to outyield inbred top crosses in order to be desirable parental material, pointing out that recombinations during the segregating generations of selfing from some of the lines giving lower yielding crosses may lead to desirable inbreds. Brewbaker and Wood (3) have reported a modification of this breeding method as adapted to sugar beets.

In 1945, Hull (11) outlined his method of recurrent selection for specific combining ability. This consists of going into an open-pollinated field and selfing 100 plants and at the same time outcrossing each of them onto a suitable inbred as a tester. A yield trial is conducted with the outcrossed seed and, from the results of this, the selfed seed representing the highest ten outcrosses is planted in rows and intercrosses made between rows. Seed from these intercrosses is bulked for the start of the next cycle. Hull maintains that continuing through three such cycles is equivalent to testing

twelve thousand plants in the original population. The commercial seed would be obtained by crossing plants from the intercrossed seed of the last cycle with the inbred used as a tester throughout the program. The criticism of this method is that if, during the process or after completion, the inbred tester was found to be susceptible to some new destructive disease, the whole process may have been wasted effort since the whole project is dependent upon the specific combining ability of the intercrossed progeny with a particular inbred tester.

Richey (21) has suggested a method which he calls multiple convergence, which is supposed to combine several small streams of germ plasm into one superior hybrid. This method is accomplished by improving two inbreds by using different non-recurrent parents in a backcross plan, and later crossing the recovered lines. The final cross could be represented as follows: $(A_b \times A_c) \times (X_y \times X_z)$ where A_b represents a recovered line of A using b as the non-recurrent parent and A_c a recovered line of A using c as the non-recurrent parent and so on. Mechanically this will be a double cross, but genetically it will be a single cross except for the characters retained from the non-recurrent parents. Data were presented on only one-half of this cross. The average yield of the recovered lines was greater than the original parent. The average of crosses between recovered lines using different non-recurrent parents was higher, but not significantly so, than the average of crosses between recovered lines using the same non-recurrent parent. This method will depend upon further results before becoming widely used, but it does appear to have possibilities of approaching the value of a single cross and still make seed production economically feasible.

Good sources of inherently self-fertile sugar beets are now available. A working understanding of the development and maintenance of male sterile strains is known. The dangers of crop failures due to diseases are somewhat alleviated by resistant varieties. It would seem that the problems of the sugar beet breeder today, as recognized by the corn breeders of some twenty-five years ago are: 1. the isolation of desirable inbreds, and 2. the utilization of these inbreds to produce superior hybrids.

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Chemical Constituents of Five Varieties Grown in Six Midwestern Factory Areas

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Improvement of the sugar beet in the past has been confined largely to selection of types high in yield, sucrose percent and disease resistance. The importance of juice purity has long been known, and it is the main factor controlling the amount of sucrose which can be extracted from the beet. However, it is only within the last decade in this country that much attention has been given to varietal differences in purity of juice. It is only recently that the non-sugar elements in beet juices have been studied for the purpose of making varietal improvements.

Dahlberg (1)[2] reported on selection for high purity in 1942 in which some reference was made to non-sugar elements. In 1950 Doxtator and Calton (3) reported on variety differences with respect to sodium and potassium. That same year Dahlberg (2) reported on many non-sugar elements in cossette samples obtained from sugar factories scattered over a wide geographic area. A study of that article by the authors of this paper resulted in plans being made to study varietal differences, not only of many of the non-sugar elements but beet yields as well, in several factory areas of the American Crystal Sugar Company.

This paper presents results obtained in 1951 on five varieties tested in six replications of plots at six factory locations for the following characteristics: yield of beets and sugar per acre, and percentage of sucrose, sodium, potassium, magnesium, calcium, chlorine, ash, sulphate, total nitrogen and purity of juice.

Materials and Methods

Five varieties were used in this experiment as follows: 6-419-X, a natural hybrid of American No. 1 and curly-top-resistant types; 8-601-0, a leaf-spot-resistant elite stock; 9-604-0, an Aphanomyces root-rot-resistant elite; 0-803, an American No. 3 Northern elite, and Commercial American No. 1.

These five were planted along with 11 other varieties in 16-variety six-replicate plot tests at Rocky Ford, Colorado; Grand Island, Nebraska; Mason City, Iowa, and Moorhead and East Grand Forks, Minnesota. In the sixth test, located at Missoula, Montana, the five varieties were part of a 12-variety test of six replications of plots. All plots were four rows wide and from 50 to 75 feet long, except at Missoula anda Rocky Ford where three-row plots were used. In the latter two tests the center row of each plot was used for yield determination. In the other four tests, at least 80 feet of the two center rows were harvested for yield.

Two samples of not less than 10 beets each were taken from all plots for sucrose percentage determination. Part of the samples of leaded filtrate used in the sucrose test in the six factory areas were sent to Rocky Ford for the other analyses. Purity of a hot digestion juice was determined at

[1] Plant Breeder and Experimental Chemist, respectively, American Crystal Sugar Company, Rocky Ford, Colorado.
[2] Numbers in parentheses refer to literature cited.

each factory by refractometer. At Rocky Ford the percentages of sodium, potassium, magnesium, calcium, chlorine and sulphate were obtained by use of the Beckman flame spectro-photometer. Ash by incineration analysis was made at Rocky Ford, from samples of pulp (dried) taken at the time sucrose analysis was made at the six factories. The data obtained from the five varieties was complete for six replications of plots at each of the six factory areas.

Experimental Results

Differences Between Varieties

In order to present the results of this experiment in concise form, extensive summarizations of the data have been made. In Table 1 is given the performance of the varieties for yield, sucrose, purity, total nitrogen, ash and the six ions: Na, K, Mg, Ca, Cl, and SO_4, as an average of the six factory areas.

Table 1. Variety Performance for Yield and Sucrose Percent, Along with Analysis Data on Nine Characters of Juice. (Average of Six Factory Areas).

	Variety							
Characteristic	6-419-X	Am. 1	8-601-0	9-604-0	0-803	Ave.	F[1]	Sign. Diff. (19:1)
Tons per A.	13.67	13.38	13.86	13.30	13.95	13.63	.56	
% Sucrose	15.77	15.29	14.80	15.17	15.65	15.34	3.70	.57
Lbs. S. per A	4305	4088	4113	4067	4379	4190	1.87	
% Na	.041	.051	.057	.055	.044	.050	2.06	.014
% K	.238	.250	.244	.233	.239	.241	2.20	.013
% Mg	.066	.066	.064	.065	.066	.065	4.00	.001
% Ca	.024	.024	.022	.023	.025	.024	1.80	
% Cl	.016	.018	.023	.019	.015	.018	4.31	.004
% Ash	.801	.797	.828	.836	.796	.812	.53	
% SO_4	.032	.033	.032	.032	.032	.032	1.88	
% Total N	.102	.092	.093	.099	.099	.097	4.10	.006
% Purity	87.13	86.86	86.58	86.37	87.03	86.79	.87	

[1] 5% point 2.87
1% point 4.43

The yield of beets and of sugar per acre given in the above table are averages of 36 plots—six plots at each of six locations. Since two samples were taken from each plot for sucrose test, this data along with other chemical analyses are averages of 72 determinations. The analysis of variance was obtained by using averages of six plots at each loction as individual performance figures, with locations being considered as replications. For the average of the six areas, F values indicate significant differences between varieties for percent sucrose, magnesium, chlorine and total nitrogen, and near significance for percent sodium and potassium.

Comparisons between varieties is of interest in this table. The variety 6-419-X was highest in sucrose, magnesium and total nitrogen, and lowest in percent sodium and potassium. American No. 1 was highest of all varieties in percent potassium and lowest in total nitrogen. 8-601-0 was lowest in percent sucrose, highest in percent sodium and chlorine and lowest in percent magnesium. 0-803 was high in percent magnesium and low in percent chlorine.

Table 2a.—Five Variety Average Results on Tonnage and Sugar per Acre Yield, by Factory Locations.

Location	Tons per A.	Percent Sucrose	Lbs. Sugar per Acre
Missoula	10.86	15.31	3,362
Rocky Ford	12.64	15.04	3,829
Grand Island	13.59	11.02	3,008
Mason City	15.27	17.83	5,433
Moorhead	11.91	17.47	4,154
East Grand Forks	17.51	15.32	5,356
Significant Difference (19:1)	1.07	.57	370

Differences Between Areas

The six factory areas where the tests were conducted represent a very wide range of soil and climatic conditions for beet growing, and, therefore, differences between the chemical constituents of beets grown in these areas might be expected. The average results for all 12 characteristics of the five varieties are given by location of test in Table 2.

Table 2b.—Five Variety Average Results of the Analyses for Nine Characteristics of Juice, by Factory Locations.

	Characteristics of Beets								
Location	Na	K	% Mg	% Ca	% Cl	% Ash	% SO_4	% TN	% Purity
Missoula	.028	.300	.048	.018	.016	.847	.031	.091	86.11
Rocky Ford	.108	.208	.060	.033	.031	.752	.031	.062	91.15
Grand Island	.094	.296	.078	.021	.038	1.143	.037	.147	79.34
Mason City	.012	.232	.069	.027	.008	.590	.030	.061	90.04
Moorhead	.013	.170	.070	.023	.007	.712	.030	.085	88.99
E.G.F.	.042	.239	.068	.018	.008	.822	.033	.135	85.11
Sign. Diff.	.014	.013	.001	.003	.004	.073	.001	.006	.96

Note: F values are highly significant for all characteristics.

The data obtained indicates very great variation in all characteristics, all of which are attributable to geographic location. At Missoula, percentages of magnesium and calcium were lower than other locations. At Rocky Ford, the highest sodium and calcium percentages were obtained. The Grand Island results show higher percentages of potassium, magnesium, chlorine, ash, sulphate and total nitrogen than at other locations. At Mason City, the percentages of sodium and total nitrogen were low. Percentages of potassium, chlorine, ash and sulphate were lowest at Moorhead. East Grand Forks was low in calcium.

Differences were also significant between areas for yield of beets, percent sucrose, pounds sugar per acre and also in percent purity of juice. Due to the difficulties in procedure for obtaining purity of juice by the refractometer method it is likely that some of the variation observed is the result of slight differences in laboratory procedure at the different factories.

Varietal Differences in Different Areas

Since the five varieties selected for this experiment were all different in origin and had been selected for use in different factory areas, it would

be expected that some differential performance at the six locations would be observed. Sucrose types such as American No. 1 commonly are slightly lower in tonnage yield than northern types such as 0-803, when tested in northern areas. American No. 1 was selected for high sucrose percent and leaf spot resistance, mainly for the Arkansas Valley of Colorado.

In order to determine comparative differences between varieties at different locations, the data obtained from each of the six plots of each of the five varieties at all six factory locations were set up and statistisally analyzed for the twelve characteristics. Significant F values obtained from this analysis for the variety-location interaction are given in Table 3.

Table 3.—Variety-Location Interaction F Values Obtained for Percentages of Sucrose, Na, Ca, Cl, and Ash.

Characteristic	F Value	Significance[1]
Percent Sucrose	1.83	*
Percent Na	2.34	**
Percent Ca	2.19	**
Percent Cl	10.61	**
Percent Ash	1.62	*

[1] 5% point—1.63. 1% point—2.00.

From this analysis it is evident that certain of these varieties did not perform in similar relationship to others at all locations of test. A study of the variations in the varieties is therefore of interest.

Of the five varieties, the hybrid variety 6-419-X was the most variable of all. This variety was lower in sucrose percent than 9-604-0 at Missoula, and significantly higher than 9-604-0 at Rocky Ford. It was higher in sucrose than 0-803 at Moorhead, and lower at East Grand Forks. Sodium content of 6-419-X at Moorhead was one-half that of American No. 1, but at East Grand Forks it was nearly double that of American No. 1. For ash, this variety was significantly higher than American No. 1 at Missoula and similarly lower at Moorhead. In calcium content at Missoula, 6-419-X ranked lowest and American No. 1 highest, and at Grand Island the reverse was true.

The percentage of chlorine was also different in two varieties at two locations. At Mason City American No. 1 was significantly higher than 9-604-0, but at Moorhead the reverse was true by a significant amount.

Table 4.—F Values for Varietal Differences Obtained for 12 Characters in Six Factory Areas.

Location	Tons per acre	% Suc.	SPA	Na	K	Mg	Ca	Cl	SO_4	Ash	TN	Purity
Missoula				0	*		**					
Rocky Ford		**	**	**			*	**	0			
Grand Island		**		**			*	0			0	0
Mason City				0			0		**			
Moorhead		*		**	0							
E.G.F.	0									*		

* 5% point—2.87
** 1% point—4.43
0 near 5% point

Differences Between Varieties at Each Location

In order to determine the characteristics of each variety at each location, a statistical analysis was made using the data from the six blocks for the 12 characteristics at the six locations. In all, 72 variance analyses were made to determine these varietal differences. In order to reduce the volume of data to be presented, individual location results have not been included. Instead, a listing is given in Table 4 of the significant and near significant F values for the twelve characters at each location.

In spite of the fact that the varieties used were different in origin and selected for different agronomic characters there was no difference between them for tonnage yield, with the possible exception of the East Grand Forks test where 0-803 (American No. 3 Northern) was highest in yield rank. Variety differences for percent sucrose were significant at Rocky Ford, Grand Island and Moorhead. Reliable sugar per acre differences between varieties were obtained at Rocky Ford.

Significant differences for percent sodium were obtained at Rocky Ford, Grand Island and Moorhead, and large differences at Missoula and Mason City. Differences for potassium were obtained at Missoula and near significant differences at Moorhead. In percent calcium, varieties were significantly different at Missoula, Rocky Ford and Grand Island, and nearly so at Mason City. Varieties differed greatly with respect to chlorine content at Rocky Ford, and at Grand Island differences were quite large. In sulphate content large varietal differences were observed at Mason City; and there were indications of similar results at Rocky Ford. Of the six test locations, East Grand Forks was the only one where varieties were different in ash content. Near significant differences in total nitrogen and purity were obtained at Grand Island.

It will be observed in the above table that greatest variability in variety performance occurred in percent sucrose, sodium and calcium. In the characteristics of potassium, chlorine, sulphate and ash, reliable differences occurred only at one location.

Table 5.—Correlation Coefficients of Eight Juice Characteristics of the Five Varieties Tested at Six Locations.

Percent of	Suc.	Na	K	Ca	Cl	Ash	SO_4	Ca & Mg
Suc.								
Na	—.98**							
K	—.26	+.22						
Ca	+.93*	—.87*	—.15					
Cl	—.97**	+.92*	+.24	—.99**				
Ash	—.73	+.74	—.44	—.80	+.75			
SO_4	—.56	+.66	+.55	—.47	+.49	+.20		
Ca & Mg	+.94*	—.87*	—.09		—.99**	—.83	—.36	

5% point—.87. 1% point—.95.

The Relationship of the Characteristics of the Five Varieties Tested

The characteristics of yield and sucrose percent are of first importance in the growing of sugar beets. It is well known that the correlation of yield and sucrose percent is negative. Despite this fact, however, varieties have been developed which are not only high in yield but also high in sucrose.

In this study of varieties, it was considered important to determine the relationship of one character with another. This was done by obtaining correlations using the co-variance analysis method. It was expected that tonnage yield between varieties would show significant differences but this did not occur, hence the yield of beets and of sugar per acre were not used for the relationship studies. Of the twelve characteristics studied, seven were used, along with a combination of two of them. These eight characteristics were all that were considered as giving reliable variation within the five varieties tested. The correlation coefficients for all pair combinations of the eight characters except one are given in Table 5.

Due to the fact that there were only five varieties in test, the significant level for correlation was extremely high. Nevertheless, there were nine of the 27 correlations which were significant; and the remainder were generally in line with the data presented by Dahlberg (2).

Positive correlations were obtained for percent sucrose with calcium, and with calcium-magnesium; and negative correlations with percent sodium and chlorine. Percent sodium was negatively correlated with calcium, and with calcium-magnesium, and positively with chlorine. Calcium and calcium-magnesium were negatively correlated with chlorine. There was no significant relationship of potassium, nor of sulphate, to other elements. Percent of ash showed a fairly high positive correlation with sodium and a similar negative relationship with sucrose. The correlation of ash and calcium-magnesium was negative, approaching the significant level.

Summary and Conclusions

The data presented indicate differences between varieties for sucrose, sodium, potassium, magnesium, chlorine and total nitrogen, as an average of the six areas. However, due to the extremely small amounts of magnesium and chlorine found it is probable that these minerals are not of as great importance in variety improvement work as other elements.

Considering test areas, the five-variety average data for the 12 characters show very great difference for all six areas. These differences were so large that it can be concluded that the area of production is the most important factor in yield and quality in sugar beet production.

Varietal characteristics were found to be different in different test areas, for percent sucrose, sodium, calcium, chlorine and ash. None of the five varieties was suitable in all six areas for these elements. These effects were, however, secondary to the main variety differences obtained.

Within each test area the major variety differences occurred in percent sucrose, sodium and calcium; with potassium, chlorine, sulphate and ash differences occurring only in one of the six test areas. These results are important for the beet breeder, since they indicate the effect of environment on sugar beet varieties.

There were eight juice characters, recorded in percentage figures, which were used for the correlation study. The results show that sucrose and calcium were positively correlated. Sucrose was negatively correlated with sodium,

and with chlorine. Sodium was negatively correlated with calcium and positively with chlorine. Chlorine with calcium gave a negative correlation. The combination of calicum-magnesium was positively correlated with sucrose, and negatively with sodium and chlorine.

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Improvement of Processing Quality of Sugar Beets By Breeding Methods

R. J. Brown and R. R. Wood[1]

Introduction

It will be fairly obvious that, from a processing viewpoint, the production of varieties of sugar beets having in their makeup a minimum of melassogenic substances would be a highly desirable and very profitable research undertaking. While the title under which this is written is very general, the writers will discuss only such data as is accumulated by their investigations on the subject, employing new techniques and instruments recently developed.

The earliest application of chemical tests, other than sugar and purity by the Great Western Sugar Company to the selection of individual beets for development of improved varieties was made in 1932. From a group of roots of good size, shape and sugar content, individuals were selected which in chemical test by the slow classical methods showed low ash and chloride content, and high percentage calcium and magnesium on ash. In 1934, roots of various varieties including progeny from the 1932 selections were tested for ash content by an electrical conductivity method, and for harmful nitrogen by a colorimetric method, and selections of individuals were made. From these selections developed what were called "Chemical Varieties." These varieties were of high sugar content and very high purity, but yield per acre fell off disappointingly, probably because of too close inbreeding resulting from the vary narrow base for selection.

With the development of new tools, suitable for mass operations in chemical analyses, chemical tests have come to the front as a basis for selections. To date chemical tests adaptable to volume operations have been developed for the determination of sodium, potassium, calcium, magnesium and raffinose.

Sodium

The method used for sodium determination utilizes the same lead clarified filtrate which is prepared for sugar test. A small volume of the filtrate is treated with a standard quantity of lithium nitrate solution and the solution is tested for sodium in a Perkin-Elmer flame photometer. Operations have been coordinated, and mechanical measuring devices, for solutions, developed to a degree permitting the testing of more than 600 individual roots per eight-hour day.

Prior to recent selection work, tests were made on a number of varieties grown in replicated plots in 1948 on a single test field. Wide variations in sodium content between varieties were demonstrated. Table 1 shows some representative results.

While within a given variety excellent negative correlations ($r = -.7$ to $-.9$) between sugar and sodium contents have been observed, when the foreign and domestic varieties are compared, higher sodium contents at given sugar contents are observed.

Large scale analyses for sodium content were first made in 1948; selections were made on the basis of sugar and sodium contents and the

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Table 1.—Sugar, Apparent Purity and Sodium Content of Six Varieties of Sugar Beets, Fort Morgan, Colorado, 1948.

Accession Number	Sugar Percent	Apparent Purity	Sodium Percent
R & G "N"	16.70	90.4	0.051
Maribo	15.79	90.2	0.072
Hilleshog	15.60	90.2	0.065
GW 201	17.12	91.7	0.023
C 305	16.28	91.2	0.028
B 359	17.18	90.7	0.029

roots grouped as given in Table 2, due consideration having first been given such characters as weight, shape, etc. One thousand roots of Variety GW304 were analyzed for sugar; low sugar roots were screened from sodium determination as an economy of time.

Table 2.—Averages of Roots in Breeding Groups of Sodium Selection.

Accession Number	No. Roots	Weight Pounds	Sugar Percent	Sodium Percent	Sugar/sodium Ratio
B474	82	2.87	13.67	0.049	279
B475	93	2.94	13.82	0.145	126
B476	54	2.50	15.97	0.045	355
B477	61	3.10	10.92	0.216	51

Tests of progeny of these selections were made in three different locations during the 1950 and 1951 growing seasons. For brevity these are given in Table 3 as the average of results obtained at the three locations.

Table 3.—Tests of Progeny of Selection on Basis of Sodium Content, 1950-51.

	Sugar in Roots Percent		Sodium in Roots Percent		Pounds Sugar per Acre	
	1950	1951	1950	1951	1950	1951
C304	17.68	17.40	0.033	0.033	8,652	8,073
B474	18.22	17.65	0.015	0.024	8,854	7,987
B475	16.70	18.01	0.023	0.031	8,233	8,015
B476	18.68	18.21	0.018	0.021	8,679	7,920
B477	17.82	17.48	0.030	0.034	8,857	8,097
LSD 5% pt.	0.32	0.24	0.002	—[1]	402	415

[1] Earlier tests had shown the LSD for sodium was very low, consequently not calculated here.

The results of the two seasons are not identical, but they demonstrate that definite reduction in sodium content was accomplished. Most variable are the results on B475. This variety is abnormal since it was selected to contain beets of both high sugar and high sodium content, reversing the normal relationship found in sugar beets.

In both seasons B474 and B476, selected for low sodium content, produced beets of significantly higher sugar content than the parent with no significant change in yield of sugar per acre. In view of all results, it appears that one can select beets on the basis of sodium content, for sugar content and associated improvement in working qualities, without significant loss in yield or total sugar per acre.

Beets of a given variety of the normal heterozygous type may show wide variations in absolute sodium content, but will show a high negative correlation between sugar and sodium content. Tests on a few inbred lines, which appear to be comparatively homozygous, show much less variation

in sodium content. Table 4 compares results obtained by analyses of three U.S.D.A. (Deming) inbred lines and one commercial G.W. variety.

Table 4.—Variability of Sodium Content in Individual Beet Roots.

Accession Number	Type	No. roots tested	Sodium Content Mean	Maximum	Minimum
1036	Inbred	10	0.044	0.051	0.038
1058	Inbred	10	0.088	0.100	0.070
1079	Inbred	10	0.038	0.060	0.028
GW201	Com'l.	25	0.035	0.106	0.015

As one might expect, after several generations of inbreeding the varieties show a much reduced variability in sodium content; it would also seem a reasonable assumption that inbreeding would tend to reduce variability in other chemical characteristics as well.

Potassium

Potassium is determined on the same sample employed for the sodium test.

Many investigators, notably those in Europe, have claimed they observe a positive correlation between potassium and the sugar content of roots. Van Ginneken (1)[2] showed an excellent correlation between the potassium content of beet leaves and the sugar content of the roots. Previous to 1950 our own investigations have shown no such correlation. Recent and somewhat extensive analysis (unpublished) indicate there may indeed be a relationship between sugar and potash but that the **r** value is negative. Possibly our beet growing areas are sufficiently well supplied with available potash in soils to permit luxury consumption by the beet at all times; it is known that in most areas of Europe potash must be applied.

Raffinose

The method used for raffinose determination was presented by the senior writer at the 1951 Boston meeting of the American Chemical Society. (2) Briefly, the method consists of obtaining a small sample of press juice from the mother beet, preparation of the juice sample for test, and test of the sample by paper chromatography. The method has been developed to a point where 50 to 100 individual roots can be tested per eight-hour day.

The method provides a degree of accuracy highly satisfactory for purpose of selection. All beets in a group of 204 were tested individually, in duplicate, for raffinose content. The comparison of results of duplicate tests is given in Table 5.

Table 5.—Comparison of Duplicate Tests of Raffinose Percent on Sugar on 204 Single Beet Roots.

Number of roots in group	Spread in observed percent raffinose on sugar between duplicates
102	zero
68	0.1
29	0.2
4	0.3
1	0.4

These beets were very high in raffinose content, ranging from 0.65 to 1.5+ percent raffinose on sugar, with a mean of 1.33 percent. Beets con-

[2] Numbers in parentheses refer to literature cited.

taining less raffinose show lower absolute variations in results of duplicate tests.

A variety of factors appear to affect the raffinose content of beets. Among these are:

1. Heredity, 2. Environment during growth, and 3. Conditions of storage after harvest.

1. Ten varieties of foreign and domestic seed were grown in six replicated plots each. Raffinose was determined on all replicates. The mean perecntage raffinose on sugar found in the ten different varieties at harvest time ranged from 0.29 to 0.49, and standard errors of the means ranged from 0.013 to 0.041. Another group of data gives results indicative of heredity differences in raffinose content. Fifty inbred varieties were grown at Longmont in plots of three replicates of each variety. The beets from all replicates of one variety were composited and tested for raffinose content at harvest time. The results range from a minimum of 0.15 percent (or less) to 0.68 percent raffinose on sugar.

2. It has long been observed that the raffinose content of beet factory liquors varies with conditions under which the beets are grown.

Indicative of these effects are results obtained on 12 varieties grown in replicated field trials in 1951 at three locations. The beets of each variety from all six replicates were composited for the raffinose tests. The results are given in Table 6. All results show the raffinose content at harvest time.

Table 6.—Raffinose Content of Beets Grown in Different Locations.

Variety No.	Percent Raffinose on sugar at harvest time		
	Longmont, Colo.	Fort Morgan, Colo.	Gering, Nebr.
1	0.33	0.28	0.54
2	0.30	0.33	0.43
3	0.30	0.40	0.63
4	0.30	0.28	0.61
5	0.38	0.28	0.48
6	0.38	0.33	0.50
7	0.30	0.33	0.58
8	0.38	0.28	0.45
9	0.33	0.35	0.49
10	0.38	0.30	0.60
11	0.30	0.33	0.50
12	0.60	0.45	0.65

The higher raffinose content of beets grown at Gering is shown in Table 7. Whether or not the higher raffinose content at Gering is associated with the lower sugar content is not as yet clearly defined.

Table 7.—Mean Composition of 12 Varieties Grown at Three Locations.

Location	Sugar Percent	Apparent Purity	Raffinose on sugar percent
Longmont	17.74	90.63	0.357
Fort Morgan	18.11	91.34	0.328
Gering	16.22	89.06	0.538

3. The raffinose content of beets increases during storage, and the quality of roots entering storage probably affects the rate of increase. Table 8 gives data on the rate of increase of raffinose during storage.

Table 8.—Increase in Percent Raffinose on Sugar in Beets During Storage.

Type of Beets	Type of Storage	Number Weeks storage	Increase in percent raffinose on sugar per week
Experimental (Low purity)	Cellar at 8° C.	7	0.076
Experimental (High purity)	Cellar at 8° C.	13.5	0.027
Commercial	Commercial pile	8	0.021

Because of the effect of storage of beets on raffinose content, all tests on beets of the 1951 season were made on beets as harvested. This was accomplishd by sampling the beets immediately after harvest and storing the rasped pulp at temperatures below 0° F. until tests could be made.

It remains to be demonstrated whether the beet which shows the minimum raffinose content at harvest time will also show minimum raffinose content after normal storage in piles, as practiced in the Rocky Mountain area.

Improvement in quality of beets following selection of individual roots for lower raffinose content awaits demonstration in the future; results of progeny tests should be available following the 1952 harvest.

Calcium and Magnesium

Methods have been developed whereby selection of individual roots on basis of calcium and magnesium content can be made when and if the geneticist decides to take these factors into consideration. The methods employ acid extraction of beet pulp to obtain essentially all of the calcium and magnesium, determination of Ca by flame photometer and Mg by difference after determination of Ca plus Mg by versene titration.

Summary

The application of the flame photometer to the mass determination of sodium in mother beets is discussed, data are presented showing variations in sodium content between varieties and results of progeny tests of selections on basis of sodium content.

The possible relationship of potassium to sugar content, in areas where soils are relatively rich in potash, is discussed briefly.

The method of determination of raffinose by paper chromatography is outlined and results are presented showing some effects of heredity, growth environment and storage on the raffinose content of beets. Progeny tests are not yet available.

Determination of Ca and Mg have been noted.

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Parent-Progeny Tests for Sodium and Potassium Content

C. W. Doxtator and H. M. Bauserman[1]

The maximum extraction of sucrose from the sugar beet is very important to the industry. Although much depends on factory operations, it is necessary that varieties be grown for processing which are high in juice quality, and thus suitable for maximum extraction.

Early in 1949 plans were made by the American Crystal Sugar Company to study all varieties used in Company areas, for the purpose of determining whether differences existed for the two minerals, sodium and potassium, since these minerals cause lowered extraction of sucrose from the beet. Part of the 1949 results were reported by Doxtator and Carlton (1)[2] in which article large varietal differences were noted.

Reference was made in this article to a 500-mother-root selection obtained from the lowest sodium-potassium variety found. This paper reports the results of the 1950 and 1951 tests on progenies from some of the roots of this selection.

The 1949 selection of 500 roots was from eight rows 400 feet long on the Experimental Station at Rocky Ford, Colorado, from the American No. 1 Elite stock 7-401a. This Elite stock is a selection of American No. 1, a variety of hybrid origin. The selection was for size and shape in the field. In the laboratory individual weights were obtained along with data on percent sucrose, sodium and potassium. The latter two determinations were made with the Beckman flame spectrophotometer on a portion of the leaded filtrate used for the sucrose test. From these data, selections were made for (A) the 25 beets highest in weight and sucrose and lowest in sodium and potassium; (B) the 25 beets lowest in weight and sucrose and highest in sodium and potassium.

The two selections were planted in the greenhouses early in 1950 for winter seed production. The beets were bagged in pairs within each selection, using Kraft bags 16 inches x 25 inches in size, to produce sib progenies. It was hoped that this procedure would result in seed lots of adequate quantity to permit a replicated plot test planting in 1950. Bolting in the greenhouses was not uniform, however, and only a small number of "pair progeny" seed lots sufficient in quantity was obtained from each selection. The seed from four progenies of each of the two selections was planted for test in 1950 in single row plots, the length of the plots being determined by the amount of seed available. Alternate rows were planted to the parent variety 7-401a.

All roots were harvested in the fall of 1950 from both the parent variety and the pair progenies. Weight, sucrose, sodium and potassium data were obtained on all beets weighing over one pound. These beets were then planted in the greenhouses for seed production during the winter of 1950-51.

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[1] Plant Breeder and Experimental Chemist, respectively, American Crystal Sugar Company, Rocky Ford, Colorado.

[2] Numbers in parentheses refer to literature cited.

Four pair bagged progenies were obtained in satisfactory seed quantity to permit a two-replicate test of single row plots 20 feet long in 19551. As in 1950, alternate rows were planted to the parent variety. In the fall of 1951, all beets from the progenies and the parent were harvested and analyzed individually as in 1950, for the same four characteristics.

Experimental Results

The two 1949 beet selections had the following average characteristics:

Type of Selection		No. Beets Selected	Weight Lbs.	Average % Sucrose	% Na	% K
Best Selection	(A)	25	3.88	17.8	.015	.140
Poorest Selection	(B)	25	2.60	13.2	.107	.274

The four pair progenies from each selection which produced a satisfactory amount of seed and which were planted in 1950 were harvested as mother beets. Average data obtained from these individual beets from the eight lines along with the parent variety are given in Table 1.

Table 1.—Average Weights and Percentages of Sucrose, Sodium and Potassium Found in Eight Progeny-lines and the Parent Variety, 1950.

1949 Selection	1950 Progeny No.	No. Beets Tested	Average Weight Lbs.	% Sucrose	% Na	% K
A	393	10	1.23	16.1	.070	.145
	395	15	2.75	16.5	.101	.156
	397	14	2.63	16.3	.071	.161
	399	10	2.68	14.9	.090	.208
B	392	15	1.37	14.5	.144	.224
	394	8	1.68	14.5	.104	.226
	396	14	2.83	12.7	.113	.275
	398	9	1.50	14.4	.108	.190
Average A Selection		49	2.32	15.95	.083	.168
Average B Selection		46	1.85	14.02	.117	.229
Average Parent Variety		62	1.71	14.80	.112	.215

The data in table 1 indicates a large difference in favor of the A selection over the B, and over the parent variety, for the four characters. However, due to the small number of roots available for comparison of lines it was decided to recheck the parent progeny relationship a second time. Accordingly, all analyzed roots of the eight lines were planted in the greenhouses in the winter of 1950-51 for seed production. Difficulties were again experienced in obtaining seed from the pair progeny bags, due to the fact that a late curly top infestation was obtained in the field in the fall of 1950. Most of the mother beets had to be discarded, with the result that only three pair progenies were available from the original A selection lines, and one from the original B selection lines for nursery plantings in 1951. All beets from the two replicates of single row plots 20 feet long from the lines, along with original parent variety from alternate rows, were harvested in the fall of 1951. Average data from the individual root analysis are given in Table 2.

In this test a somewhat larger number of beets was available for analysis from the original A selection. The stand in the plots averaged 14 beets per

20 feet of row, which was appreciably better than in the 1950 test.

The results of the 1951 tests indicate that the A selection progenies performed similarly to those of 1950 for sucrose and sodium percent, when compared with the B line, and the parent variety. Differences between all three for yield and percent potassium were extremely small, however.

Discussion

The 1950 data indicate rather large differences between progenies and the parent variety for all four characteristics even though number of beets tested was very few. The larger number of individuals tested in 1951 showed similar differences, as an average, on two characters, percentage of sucrose and sodium. Seed quantities were not available either in 1950 or 1951 for adequate plot test to determine whether differences in yield existed between progeny selections, nor of relationships between yield and other characters. Differences in percent potassium in these tests have been erratic. It is possible that breeding for lowered amounts of this chemical may be more difficult than for sodium.

Table 2.—Average Weights and Percentages of Sucrose, Sodium and Potassium Found in Four Progeny Lines and the Original Parent Variety, 1951.

Orig. 1949 Selection	1951 No.	No. Beets Tested	Average Weight Lbs.	Average % Sucrose	Average % Na	Average % K
A	528	20	2.46	15.18	.054	.384
	529	25	2.04	15.98	.045	.337
	531	22	1.89	14.63	.080	.310
Average A Selection		65	2.13	15.26	.060	.344
B	530	23	2.20	14.90	.086	.335
Average Original Parent (4 alternate rows)		77	2.12	14.67	.085	.347

Summary

The results of two years' testing of selected progenies obtained from a variety high in sucrose and low in sodium and potassium indicate that improvement in sucrose and sodium content is possible by simple breeding methods.

Improvement in yield along with sucrose and sodium was not clearly demonstrated.

Potassium content in the progenies tested in 1951 did not indicate appreciable change from the parent variety.

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Relationship Between Root Weight, Glutamic Acid and Sucrose Content of Inbred Lines of Sugar Beets[1]

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Studies on the glutamic acid content of commercial varieties of sugar beets under diverse environmental conditions have indicated the value of this measurement in distinguishing the physiological processes involved in the growth and storage mechanism of the beet (1, 2, 3).[3] The enormous variations found in glutamic acid content from beet to beet (4) suggested that genetics might have an important bearing on this characteristic. If this could be established and a series of inbred lines investigated, correlations might be revealed between sucrose, glutamic acid and weight which were not apparent in the more or less heterogeneous material from commercial varieties. Better knowledge of these physiological relationships should lead to a more productive breeding program.

In 1947, eight beets each from eight inbred lines, self-pollinated for several generations, were sampled by removing a wedge-shaped sample of pulp from each beet. In order to obtain an adequate sample for analysis, the beets selected were above average size for their line, but they were all sufficiently homozygous for leaf, petiole and root characteristics to be representative of the line.

The heritability of glutamic acid was clearly evident even in this small series. There were highly significant differences between lines in glutamic acid as well as sucrose (Table 1). The tremendous variation previously noted in the glutamic acid content of individual beets from commercial lines was reduced in some of these strains by more than 50 percent. There was a similarity in glutamic acid content of closely related lines 300, 301 and 304, and in lines 324 and 327. The relatively high glutamic acid of the latter lines and the low content of 322 was confirmed in a subsequent planting in 1949 of seed from one selfed plant out of each of these lines (5). Although there was some tendency for lines high in sucrose to have high glutamic acid and small weight, there was no correlation between glutamic acid and weight.

In 1950, a much larger series of inbred lines was selected. Ten beets from each of 43 lines, self-pollinated from four to 10 generations, were stored in the root cellar at Fort Collins until February when they were packed in wet sphagnum moss and shipped to Woodland. The beets were in excellent condition on arrival. They were weighed and sucrose and glutamic acid determinations (4) made on isopropanol extracts of the pulp obtained from a diagonal coring through each beet.

The beets ranged in size from 0.46 to 2.71 pounds; in sucrose percentage from 11.3 to 18.9, and in glutamic acid from 0.03 to 1.05 percent. The range of individual glutamic acid values within a line was extremely nar-

[1] The authors are indebted to Mr. G. W. Deming, Agronomist, U. S. Department of Agriculture at Fort Collins, Colorado, who developed and contributed the inbred lines tested here. Without his assistance in the selection, and sampling of this material this work would not have been possible. The sucrose measurements on the 1947 lines were also made by Mr. Deming. We wish to express our appreciation for his helpful advice, encouragement and assistance throughout this study.

[2] Research Division, International Minerals and Chemical Corporation.

[3] Numbers in parentheses refer to literature cited.

row in some lines and enormously great in others. This variation did not seem to be influenced by the degree of inbreeding, since lines self-pollinated eight to 10 generations did not generally show less variation than those selfed four or five generations. Part of the variation could probably be due to the pronounced effect of soil nitrogen on glutamic acid and to a lesser extent on sucrose and weight, but this effect cannot be measured in an unreplicated experiment.

In spite of these large individual variations, wide differences between lines were evident in glutamic acid as well as sucrose and weight. Statistical calculations of significant differences between lines require data which follow a normal frequency distribution and have a variance independent of the mean. This was the case for sucrose, and Figure 1 indicates a nearly

Table 1.—Comparison of Inbred Lines Grown in Colorado in 1947.

Line	Wt. in Lbs.	% Sucrose	% GA
296	1.81	13.7	.18
300	1.01	13.7	.09
301	1.08	16.0	.22
304	1.14	16.0	.12
308	1.36	11.3	.06
322	1.62	10.1	.09
324	1.23	15.0	.32
327	1.26	14.3	.51
Sig. Dif. 5% Point	19%	1.2	66%

homogeneous variance. As previously reported (4), and as is clearly illustrated in Figure 3, the range of variation in glutamic acid within lines increases as the average glutamic acid content of the line increases, up to approximately 0.3 percent. Beyond this value it approaches a normal distribution. The logarithmic transformation of the data previously recommended is somewhat insufficient in this experiment below 0.3 percent and excessive above that level.

A transformation yielding a variance unaffected by the mean was accomplished by a procedure similar to that described by Bartlett (5). The arithmetic mean glutamic acid values for each line were plotted against the reciprocal of the standard deviation and a smooth curve drawn, extrapolating this to the error of the assay at 0 percent glutamic acid. This curve was integrated numerically to give $f(G) = \int_0^G (1/\sigma G)\, dG$ (Table 2). This transformation yielded a variance independent of the mean and reduced heterogeneity greatly, although wide discrepancies from a homogeneous variation remained (Figure 4). This relationship should prove useful for trans-

Table 2.—Transformation Function for Glutamic Acid.

$$f(G) = \int_0^G \frac{dg}{\sigma_G}$$

% GA	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.00	0	2.09	3.39	3.93	4.14	4.32	4.48	4.63	4.75	4.86
.10	4.95	5.03	5.10	5.17	5.23	5.28	5.32	5.36	5.40	5.44
.20	5.47	5.50	5.53	5.55	5.58	5.60	5.62	5.64	5.66	5.68
.30	5.70	5.71	5.73	5.74	5.76	5.77	5.78	5.79	5.80	5.82
.40	5.83	5.84	5.85	5.86	5.87	5.88	5.89	5.90	5.91	5.92

When % GA > 0.425, f(G) = 5.427 + % GA

Figures 1-4. Relationship between mean and variance of sucrose, glutamic acid, and weight values for 10 beets from each of 43 inbred lines of beets.

Figure 1.

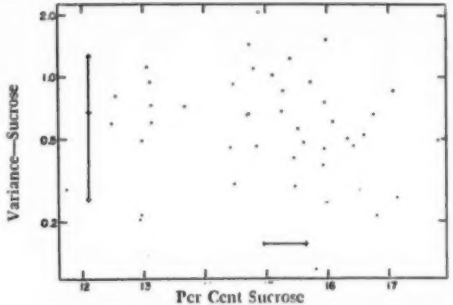


Figure 3.

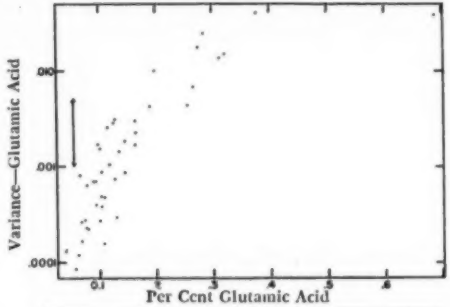


Figure 2.

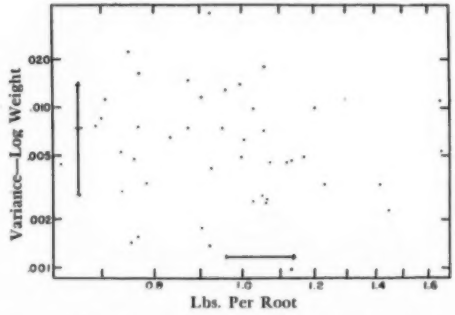
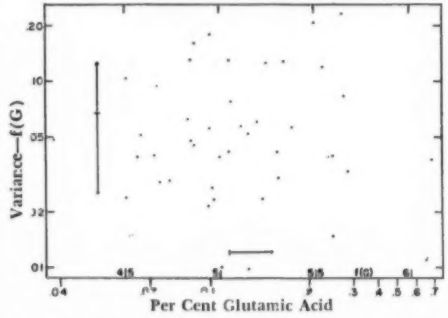


Figure 4.



Each point represents the variation of the individual values around the mean of their respective inbred line. The vertical arrows indicate the range of variance which would be expected at the 95 percent interval for a ten-beet sample from a normal population; cross bar indicates the average variance obtained for the 41 lines. Horizontal arrows show the size of the least significant difference (5 percent level) for comparison of two means; cross bar denotes general average of all lines. Variance for sucrose is nearly independent of mean (Figure 1, upper left). Increasing variance of glutamic acid with increasing mean glutamic acid (Figure 3, upper right) indicates the necessity for transformation of scale of this measurement (Figure 4, lower right). Figure 2, lower left, indicates that log transformation is adequate for weight.

forming experimental data on glutamic acid whenever there is a wide range of values. It has the disadvantage of requiring that the data be expressed in terms of the transformation function of glutamic acid [f(G)] rather than in percent units for the application of confidence limits.

Data on root weight also required transformation—but use of the logarithm was sufficient (Figure 2) to eliminate any relation between variability and average size. Variability was again much larger than expected from the normal curve of error.

With glutamic acid and weight measurements transformed to give as homogeneous error variation as feasible, it is possible to evaluate differences between the various lines. In Table 3, the lines have been divided into 10 groups based on a 1 to 10 rating from high to low sucrose, glutamic acid and weight.[4] Within each sucrose rank, the lines have been evaluated from the standpoint of all three measurements. The L. S. D. for each measurement is indicated and in general there is a significant difference only between alternate rankings. More than normal variations within any one line have been indicated also. These do not seem to be correlated with the number of generations the line was self-pollinated, which is shown in the last column of the table. Lines high in glutamic acid appear to have more variation in sucrose than do low glutamic acid lines (Figure 5). This correlation helps to explain the slightly high or low variability of a few strains, but the implications of such a correlation are not yet clear.

Only three lines, 997, 694 and 981, were above average in all three measurements. All of the beets in 997 had outstandingly high glutamic acid, averaging 0.69 percent, which is more than double that of the next highest line, and 18 times that of the lowest GA line.

There were highly significant differences between lines in sucrose, glutamic acid and weight (F values: Sucrose 31.39, glutamic acid 24.72, weight 13.3; D. F. 42/387). The range of glutamic acid values in the lines within one rank of sucrose was very large. This indicated absence of correlation should permit the selection of high sugar lines of either high or low glutamic acid.

The general pattern of correlation between the measured variables is as follows:

	DF	r_{SG}	r_{SW}	r_{GW}
Between lines	41	—.23 n.s.	—.34[1]	+.23 n.s.***
Within lines	386	—.25[2]	—.12[1]	+.21[2]

[1] Significant difference at the 5% level.
[2] At the 0.1 percent level.

The small, significant, negative correlation of sucrose—weight and probably the method of selection used in the breeding of these strains prevents extremely high sugar—high weight and low sugar—low weight combinations. These excepted, the low level and non-significance of the correlations of GA—sucrose and GA—weight between lines indicates that it should be possible to obtain almost any type of combination of sucrose—GA—weight desired.

[4] In terms of standard deviation the range of glutamic acid was found to be about equal to that of sucrose but that of weight was smaller. Accordingly, in order to make significant differences in rank equal in all three measurements, weight is rated 2 to 8 instead of 1 to 10.

glutamic acid (Figure 3, upper right) indicates the necessity for transformation of data. Figure 2, lower left, indicates that log transformation is adequate for weight.

Within lines, glutamic acid was correlated negatively with sucrose and positively with weight. Both of these are highly significant, but they are also very small and do not invalidate the aforesaid conclusions. On the other hand, this does not infer that control of the three measurements is by any means independent. Nine of the lines showed three types of deviation from the average pattern of correlation. Extreme examples of these three types are as follows:

Strain	DF	r_{SG}	r_{SW}	r_{GW}
731	8	—.90***	—.85**	+.94**
721	8	—.51 n.s.	+.81**	—.72*
975	8	+.83**	+.37 n.s.	+.28 n.s.

The pattern of correlation shown by 731 also appeared in lines 695, 706, and 730 and is an extreme case of the usual pattern. It is readily identifiable as caused by variations in nitrogen fertility and is the major component of the variation between beets within a line. Possibly, a few of the beets in these lines were quite nitrogen-deficient and the average sugar reported is too high and glutamic acid low.

Weight may be positively correlated with sucrose as in 721 when it is negatively correlated with glutamic acid and is identifiable as caused by changes in growth potential (2) at low nitrogen status such as might be caused by differences in competition.

Glutamic acid may be positively correlated with sucrose as in line 975 if there is no correlation with weight; otherwise, sucrose and glutamic acid are negatively correlated (Figure 6). The pattern shown by 975 also appeared in 727, 733 and 905 and its cause is not apparent. It is similar to effects observed in commercial beets resulting from changes in storage potential or in growth potential at high nitrogen status (2, 3).

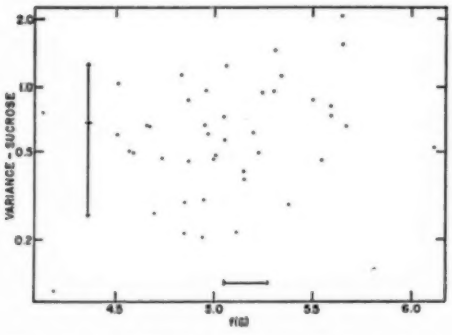


Figure 5. Sucrose variance increases with increasing mean glutamic acid of inbred line. Each point represents the variation of the individual values around the mean of their respective inbred line. The vertical arrows indicate the range of variance which would be expected at the 95 percent interval for a ten-beet sample from a normal population; cross bar indicates the average variance obtained for the 43 lines. Horizontal arrows show the size of the least significant difference (5 percent level) for comparison of two means; cross bar denotes general average of all lines.

Table 3.—Comparison of Lines Ranked According to Sucrose, Glutamic Acid and Weight.

1950 No.	Rating SGW[1]	Percent Sucrose	Percent Glutamic Acid	Weight	Total Selfings
955	1-8-7	17.8	.07	0.77	S4
706	2-4-7	17.1	.21[3]	0.76	S4[5]
975	2-8-7	17.1	.08	.74	S9
837	2-7-5	16.8	.09[3]	1.03	S8
997	3-1-5	16.6	.69	1.06	S4
793	3-7-4	16.4	.08	1.13	S6
730	3-8-7	16.7	.07	.71	S5
786	3-8-7	16.3	.07	.77[3]	S7
694	4-3-5	16.0[3]	.28	1.01	S4
905	4-5-6	16.1	.13	.92[3]	S8
981	4-5-5	15.9	.13	1.00	S9
701	4-7-6	16.0	.09[3]	.90	S7
727	4-10-5	16.0	.04	1.06	S8
673	4-6-2	15.6	.11	1.65	S7[5]
978	4-6-8	15.7	.10	.63	S9
832	4-6-4	15.5	.11[3]	1.12	S8
715	4-10-7	15.8	.04	.69	S9
779	4-5-7	15.5	.13	.70	S8
849	4-3-6	15.4	.11	1.13	S8
712	4-7-6	15.5	.09	.92	S8
695	5-3-6	14.9[3]	.27[4]	.92	S4
950	5-5-5	14.8	.16[3]	1.03	S4[5]
692	5-8-3	15.2	.07	1.42	XS4
876	5-7-7	15.3	.09	.79	XS5
691	5-6-7	14.9	.11	.74	XS4
716	5-8-7	15.1	.06	.76	S8
810	6-3-5	14.7	.29	1.05	S8
807	6-4-6	14.4	.23	.90	S8
883	6-5-2	14.5	.14	1.65	XS4
784	6-5-5	14.7[3]	.16	1.00	S8[5]
689	6-6-6	14.7	.10[3]	.87[3]	S4
838[2]	6-6-7	14.5	.10	.77	XS5
731	7-6-5	13.7	.11	.96	S9
831[2]	8-3-6	13.1	.25	.87	XS5
677	8-5-4	13.1	.16	1.17	S4[5]
770	8-5-3	13.0	.14	1.45	S10
733	8-6-5	13.0	.12	1.05	S9
756	8-6-4	13.0	.10	1.20	S10
757	8-6-5	13.1	.10	1.07	S10
752	8-7-7	13.1	.09	.75	S10
846[2]	9-3-5	12.6	.25	.95	XS5
721	9-8-5	12.5	.06	1.06[3]	S8
891[2]	10-4-4	11.7	.17	1.23	XS5
LSD 5% Point		0.7	36%	19%	

[1] Rating SGW: Rating Sucrose, Glutamic Acid, Weight.
[2] Red beets, or originated from a cross with a red garden beet.
[3] Greater than average variation within strains.
[4] Extremely large variation.
[5] Obvious outpollenation found or suspected in one or more root generations of the line.

It seems likely that within lines the true picture of the correlations between sucrose, glutamic acid and weight is generally obscured by at least three important environmental factors operating simultaneously, any one of

TABLE 4. - COMPARISON OF RELATED LINES

LINE	ORIGIN	ROOT GENERATION SEPARATED	TOTAL SELFINGS	STRAIN NO.	GA %	SUCROSE %	WT. (LB.)
		1947 STRAINS					
A.	FLAT FOLIAGE	S3 — R3	S5	324	.31	15.0	1.23
		S3 — R3	S5	327	.50	14.3	1.26
B.	FLAT FOLIAGE	S5 — R5	S8	300	.09	13.7[1]	1.01
		S5 — R5	S8	304	.12	16.0	1.14
		S5 — R5	S8	301	.22	16.0	1.08
		1950 STRAINS					
C.	CESENA	S1 — R1	S4	689	.10[1]	14.7	.87
		S1 — R1 — S3 — R3	S4	695	.27	14.9	.92
		S1 — R1 — S3 — R3	S4	694	.28	16.0[1]	1.01
D.	HILLESHÖG	?S2 — R2	S4	997	.69[1]	16.6	1.06[1]
		?S2 — R2	S4	706	.21	17.1	.76
E.	UNKNOWN	S3 — R3	S9	715	.04	15.8	.69
		S3 — R3 — S7 — R7	S9	731	.11	13.7	.96
		S3 — R3 — S7 — R7	S9	733	12	13.0	1.05
F.	PIONEER S2 X F4 (S3) UNKNOWN RED	XS1 — S4 — R4	S5	831	.25	13.1	.87[1]
		XS1 — S4 — R4	S5	846	.25	12.6	.95
		XS1 — S4 — R4	S5	891	.17[1]	11.7[1]	1.23[1]
G.	FLAT FOLIAGE COMMERCIAL	S5 — R5 — S7 — R7	S8	807	.23	14.4	.90
		S5 — R5 — S7 — R7	S8	810	.29	14.7	1.05
		S5 — R5 — S7 — R7	S8	832	.11	15.5	1.12
		S5 — R5 — S7 — R7	S8	849	.11	15.4	1.13
		S5 — R5 — S7 — R7	S8	837	.09	16.8[1]	1.03
H.	FREDRIKSEN FF	S6 — R6	S10	770	.14[1]	13.0	1.45[1]
		S6 — R6	S10	752	.09	13.1	.75
		S6 — R6 — S9 — R9	S10	756	.10	13.0	1.20
		S6 — R6 — S9 — R9	S10	757	.10	13.1	1.07
J.	FLAT FOLIAGE COMMERCIAL	S7 — R7	S9	975	.08	17.1[1]	.74
		S7 — R7 — S8 — R8	S9	978	.10	15.7	.63
		S7 — R7 — S8 — R8	S9	981	.13	15.9	1.00[1]

[1] SIGNIFICANT DIFFERENCE 5% POINT

S - SEED GENERATION

R - ROOT GENERATION

which would produce large measurable correlations if the other two remained constant.

Several of the 43 lines in the 1950 series were more or less closely related. Twenty-three diverse lines established from a common ancestor of succeeding generations were produced from seven of the original lines. The pronounced likeness between closely related lines in glutamic acid as well as sucrose and weight is evident in Table 4. The lines have been listed in order from S1 to S7, depending upon the first generation at which separation of lines took place. The mark, ', denotes significant differences between lines in any one characteristic. There were significant differences between lines in E, F and G (as indicated by differences in all three characteristics) where separation took place at the S_3, S_4 or S_5 root generation, respectively. Subsequent separation at the S7 root generation in G or in J did not result in significantly different lines. The close relationships of the lines high in glutamic acid (over 0.2 percent) is particularly interesting. The two high lines in 1947 were from a common origin; the eight lines in 1950 were derived from four original lines, two of which also had relatively high sucrose. This general close agreement between related lines in glutamic acid as well as sucrose constitutes good evidence for the heritability of this characteristic.

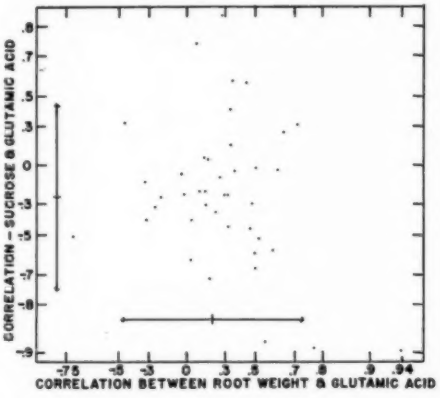


Figure 6. Points represent correlations between root weight and glutamic acid and between sucrose and glutamic acid within each of 43 inbred lines of sugar beets. Each arrow indicates the 95 percent interval of expected correlations if 10 beet samples were taken from a normal population with a correlation equal to the average correlation (marked with cross bar) found within lines measured .

Summary

Ten beets each from 43 inbred sugar beet lines grown in Colorado in 1950 were weighed and analyzed individually for glutamic acid and sucrose. The glutamic acid values, which varied from 0.03 to 1.05 percent, showed a remarkable relationship between mean and variance. A table of values of a transformation function is presented which practically eliminates this difficulty and facilitates the analysis of variance of glutamic acid data.

The inbred lines have been classified on the basis of a 1 to 10 rating from high to low sucrose, glutamic acid and weight. There were significant differences between the lines in glutamic acid as well as sucrose and weight. There was no correlation between lines in glutamic acid and sucrose, or

glutamic acid and weight which should make possible the selection of high sucrose lines of either high or low glutamic acid.

Within lines, there were small but highly significant correlations; negative, for glutamic acid and sucrose; and positive, for glutamic acid and weight. Factors, probably environmental, appear to be operating to balance these correlations and prevent, at the present time, a true measure of existing relationships.

The likeness between closely related lines is very striking and the heritable character of glutamic acid is strongly indicated.

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A Genetic Study of Monogerm and Multigerm Characters in Beets

V. F. Savitsky[1]

Introduction

Monogerm beets were found in the variety Michigan Hybrid 18 in Oregon in 1948. Two of these monogerm plants, SLC 101 and SLC 107, proved to be self-fertile and two inbred lines were produced from them (8 and 9).[2] These original inbred lines had apparently been selfed for five to seven previous generations because of uniformity shown in many characters. They were homozygous for the monogerm character, self-fertility and red hypocotyl color. The monogerm character remained constant in different environments for the inbred line SLC 101 during three additional generations of controlled selfing or crossing offspring inter se.

The Basic Gene *m* for the Monogerm Character

F_1 Generation

All F_1 hybrids were multigerm from numerous crosses between SLC 101 with different multigerm varieties of sugar beets, fodder beets, red table beets and Swiss chard. The multigerm character was dominant, but dominance was not complete in F_1 hybrids (7). The number of flowers per flower cluster was less in the F_1 hybrids than in the multigerm parents (Table 1).

The number of highly multiple flower clusters decreased in F_1 hybrids when compared with the multigerm parents. F_1 plants also developed some monogerm fruits. The percentage of monogerm fruits in F_1 hybrids increased rapidly when SLC 101 was crossed to double-germ plants (Table 1). In F_1 beets derived from hybridization to the double-germ clone 4, the percentage of monogerm fruits reached 51 percent of the total (Table 1). However, these heterozygous plants always developed seedballs in the axils of lateral branches while in the homozygous monogerm SLC 101 the seedballs were never located in the floral axils.

Table 1.—Number of Flowers Per Flower Cluster in F_1 Hybrids and Their Parents.

Parental varieties and offspring	Generation	Flowers per flower cluster						Flowers per 100 flower clusters
		1	2	3	4	5	6	
		%	%	%	%	%	%	Number
Monogerm SLC 101	P	100	—	—	—	—	—	100
Monogerm SLC 107	P	100	—	—	—	—	—	100
Multigerm SL 92	P	3	55	28	13	1	—	254
SLC 92 x SLC 101	F_1	6	81	13	—	—	—	207
SLC 92W x SLC 107	F_1	65	19	1	—	—	—	206
Clone 4, double-germ	P	7	93	—	—	—	—	193
Clone 4 x SLC 101	F_1	51	49	—	—	—	—	149

F_2 Generation

Seed obtained from F_1 plants from self-pollination under paper bags was planted as separate progenies. These different F_2 populations were

[1] Collaborator, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, in cooperation with the Curly Top Resistance Breeding Commttee.

[2] Numbers in parentheses refer to literature cited.

Table 2.—Segregation for Multigerm and Monogerm Beets from F_2 Hybrids, Salt Lake City, 1950 and 1951.

1950 greenhouse and field experiment				1951 field experiment				1951 field experiment Reciprocal hybrids			
	Classification of offspring				Classification of offspring				Classification of offspring		
Population Number	Multigerm	Monogerm	Total	Population number	Multigerm	Monogerm	Total	Population number	Multigerm	Monogerm	Total
	No.	No.	No.		No.	No.	No.		No.	No.	No.
1 G[1]	22	6		6	28	13	41	37	26	8	34
1 F[2]	24	8	60	7	24	11	35				
				8	25	7	32	38	22	7	29
2 G	25	8		9	38	8	46				
2 F	61	30	124	10	21	8	29	39	21	6	27
				11	47	17	64				
3 G	23	7		12	28	10	38	40	40	16	56
3 F	39	14	83	13	7	2	9				
				14	17	5	22	41	15	6	21
4 G	23	7		15	15	6	21				
4 F	79	24	133	16	17	5	22	42	10	3	13
				17	13	3	16				
5 G	25	10		18	23	8	31	43	21	8	29
5 F	57	18	110	19	16	8	24				
				20	12	12	24	44	16	6	22
				21	15	4	19				
				22	21	6	27	45	26	8	34
[1]G indicates grown in greenhouse				23	19	8	27				
				24	15	3	18	46	12	3	15
[2]F indicates grown in the field				25	38	13	51				
				26	5	1	6	47	27	13	40
				27	26	8	34				
				28	6	1	7	48	27	8	35
				29	23	10	33				
				30	18	5	23	49	25	7	32
				31	23	7	30				
				32	20	5	25	50	19	6	25
				33	33	9	42				
				34	13	4	17				
				35	38	13	51				
				36	19	6	25				
Total	378	132	510		663	226	889		307	105	412
3:1 ratio	382.5	127.5	510		666.75	222.25	889.0		309.0	103.0	412.0
Deviation	—4.5	+4.5	.....		—3.75	+3.75	.....		—2.0	+2.0	.....
X2	0.2117				0.8436				0.05174		
Probability	0.70 to 0.50				0.5 to 0.3				0.9 to 0.8		

studied for two years in the field and the greenhouse at Salt Lake City. The number of monogerm segregates in all cases was close to 25 percent (Table 2).

All X^2 values in Table 2 are low and show good agreement between observed and expected ratios. This indicates that the monogerm parental lines were homozygous *mm* with respect to a single gene for the monogerm character. With reciprocal hybridization, when the monogerm SLC 101 was used as the female parent and multigerm beets as pollinators, there was no change in type of segregation. F_2 hybrids obtained from hybridization of the monogerm SLC 101 to multigerm fodder beets, red table beets and Swiss chard also showed segregation in agreement with the monohybrid scheme.

Table 3.—Segregation for Monogerm and Multigerm Character in the First Backcross Generation.

Parentage of hybrids	Classification of offspring		
	Multigerm	Monogerm	Total
	Number	Number	Number
$F_1 Mm$ x SLC 101 *mm*	43	42	85
mm x F_1 *Mm*	28	27	55
do.	16	18	34
do.	19	20	39
Total observed	106	107	213
Expected 1:1 ratio	106.5	106.5	213
Deviation from expectation	0.5	0.5	
X2	0.0023		
Probability	0.0047		

First Backcross Generation and F_3 Lines

The monohybrid type of segregation was apparent also when F_1 hybrids were crossed back to the recessive monogerm parent SLC 101 (Table 3). The segregation for type of fruits in b_1 backcross populations gave results close to the 1:1 monohybrid ration.

In 19 F_3 lines, derived from selfing monogerm F_2 plants from hybrids between SLC 101 and multigerm beets, about 400 plants were produced in 1951. All of these F_3 plants appeared to be monogerm. This indicates that the monogerm character is caused by one recessive gene in the homozygous condition (*mm*) (10).

Genes Which Modify the Effect of the Basic Gene *m*

The different number of flowers per flower cluster in different F_1 hybrid combinations indicates that some other genes take part in the development of multigerm seedballs besides the gene which is responsible for the monogerm character. Some homozygous monogerm *mm* plants in the F_2 generation produced a few double-germ fruits on the basal part of the main floral axis just above the lateral branches. Sometimes solitary double-germ fruits were observed on the basal part of some lateral branches while other branches produced only monogerm fruits.

Population studies of the F_2, F_3 and the first backcross generation showed that in many cases the appearance of the few double fruits is caused by genes which modify the action of the basic *m* gene.

From 201 monogerm plants derived as F_2 segregates at Salt Lake City in 1951 (Table 4), 65 plants or 32.3 percent developed such solitary double-germ fruits. A few solitary double fruits were also observed on 29.7 percent of the monogerm plants grown in the greenhouse during 1950 and 1951.

Segregation of these modifying genes is distinct from the segregation of the basic *m* gene. The percentage of monogerm segregates carrying the basic *m* gene is always very close in different F_2 families and approaches the expected 3:1 ratio. The percentage of monogerm segregates with a few double-germ flowers is irregular in different F_2 progenies. Hybrids receive the genes modifying the action of the basic *m* gene from the genotype of the multigerm parent. Therefore in some hybrids monogerm plants in the

F_2 generation develop very few of the solitary double-germ fruits or none at all. In other F_2 families 30 to 70 percent of the monogerm plants produced a few double fruits.

The F_2 segregates which were absolutely pure for monogerm seed and monogerm segregates with a few double-germ fruits produced different F_3 lines after selfing. From 28 F_3 lines derived from pure monogerm F_2 plants about 400 offspring were grown, all of which appeared to be pure monogerm. From 11 F_3 lines, derived from monogerm F_2 plants bearing a few double-germ fruits, about 150 plants were grown of which 31.81 percent bore some double-germ fruits. The total percentage of these double-germ fruits on monogerm plants was never high. Usually there were not more than about two to five doubles per 1,000 monogerm fruits. It is highly probable that the action of the basic *m* gene is modified by other genes with less influences. In some cases these modifying genes are dominant and in other cases recessive. Special crosses have been made to study this question.

Table 4.—Differences Between F_2 Populations Concerning Development of a Few Double-germ Fruits on Homozygous Monogerm *mm* Plants.

Origin of F_2 hybrids	Classification of offspring					
	Monogerm plants bearing double-germ fruits		Pure monogerm	Total *mm* plants	Multi-germ plants	Total plants
	Percent	Number	Number	Number	Number	Number
F_2 hybrids in which most monogerm plants did not bear double-germ fruits						
Oberndorf x SLC 101	0.0	—	11	11	32	43
Peragis x SLC 101	0.0	—	6	6	15	21
SL 92 x SLC 101	0.0	—	10	10	19	29
SL 92 x SLC 101	7.14	1	13	14	51	65
SLC 100 x SLC 101	11.11	1	8	9	31	40
LSR sugar beet x SLC 101	12.50	1	7	8	31	39
Mammoth x SLC 101	16.67	1	5	6	15	21
Barres x SLC 101	18.18	2	9	11	26	37
Total		6	69	75	220	295
F_2 hybrids in which many monogerm plants produced a few double-germ fruits						
SL 92 x SLC 101	27.27	3	8	11	29	40
Swiss chard x SLC 101	33.33	3	6	9	24	31
Egyptian x SLC 101	33.33	4	8	12	29	41
Clone 4 x SLC 101	38.47	5	8	13	29	42
SL 92 x SLC 107	45.45	5	6	11	21	33
Red table beet x SLC 101	46.15	6	7	13	42	55
Ovana x SLC 101	50.00	7	7	14	47	61
SL 941 x SLC 101	52.00	13	12	25	62	87
Klein E x SLC 101	72.22	13	5	18	49	67
Total		59	67	126	332	457

The monogerm character was found to be clear-cut and constant, whereas the secondary character with regard to development of a few double-germ fruits was highly variable. Some F_2 monogerm plants like the original monogerm beet SLC 101 developed fasciated floral axes. These fasciated floral axes often bear phenotypic double-germ fruits, double-germ fruits with two bracts, single flowers with a sepal number higher than five, or monogerm fruits with two bracts. Monogerm F_2 plants as well as monogerm plants from the inbred line SLC 101 may show these abnormalities and may pro-

duce pure monogerm progenies in which some plants may develop the same abnormalities caused by fasciation.

Linkage Between a Gene for Late-Bolting Tendency and the Gene *m*

Monogerm inbred lines derived from SLC 101 and SLC 107 are very late bolting. They usually started to flower 15 to 20 days later than ordinary sugar beets. The original monogerm plants from which SLC 101 and SLC 107 were derived (Table 5) were also late bolting. When found in Oregon they were only in blossom when the seed crop for the variety Michigan Hybrid 18 was ripe and ready for harvest. The monogerm beet seed would have been lost if this seed crop had been harvested by the usual harvesting machinery. The concentration of genes responsible for the monogerm character is very low in populations of sugar-beet varieties because of elimination of late-bolting plants by natural and artificial selection. This explains the scarcity of monogerm mutants in beet populations and the difficulty of their discovery.

When SLC 101 was crossed with ordinary sugar beets, some very late-bolting plants appeared in F_2 which with usual storage conditions did not bolt even the second year. To avoid the appearance of non-flowering plants, all F_1 and F_2 hybrids and their parents were exposed to very prolonged thermal induction. Through the advice from Dr. F. V. Owen, all potted plants were placed in the cold frame for the entire winter. After this prolonged low-temperature treatment with plants held in the cold frame, all F_1 and F_2 plants developed seedstalks within 30 to 50 days. The F_1 hybrids, in spite of the large genetic diversity of their multigerm parents and their derivation from various crosses with different varieties of sugar beets, fodder beets and red table beets with the monogerm self-fertile line SLC 101 flowered

Table 5.—Linkage Intensities in F_2 and Backcross Populations for Genes Responsible for Type of Fruit and Earliness of Flowering, Salt Lake City, 1950 and 1951.

Year		Classification of offspring					
		Multigerm		Monogerm			
		Early	Late	Early	Late	Total	Crossing over[1]
		Number	Number	Number	Number	Number	Percent
		F_2 Populations					
1950	Observed	215	44	37	56	352	
	Expected 9:3:3:1	198	66	66	22	352	
							25.3 ± 1.86
1951	Observed	386	61	79	86	612	
	Expected 9:3:3:1	344.25	114.25	114.25	38.25	612	
							25.8 ± 1.43
		Population from First Backcross Generation					
1951	Observed	30	14	15	26	85	
	Expected 1:1:1:1	21.25	21.25	21.25	21.25	85	
							34.2 ± 3.46

[1] Crossing over calculated from Immer's product method (2).

at the same time as ordinary multigerm varieties and significantly earlier than the monogerm line SLC 101 (Figure 1).

In the F_2 generation both multigerm and monogerm segregates showed great variability in time of flowering (Figure 2), but most of the multigerm plants flowered earlier than the monogerm plants. A few F_2 multigerm

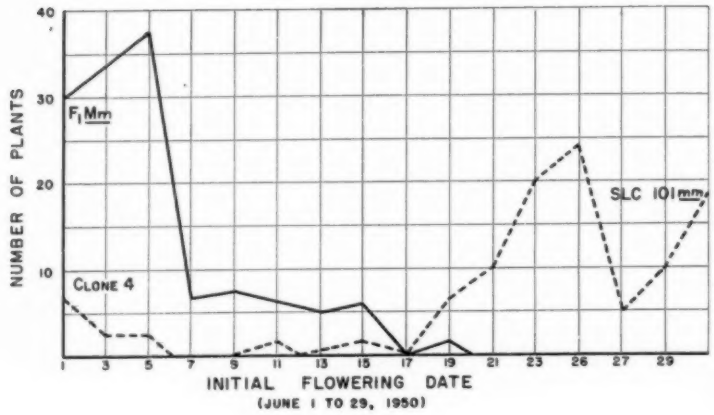

Figure 1.

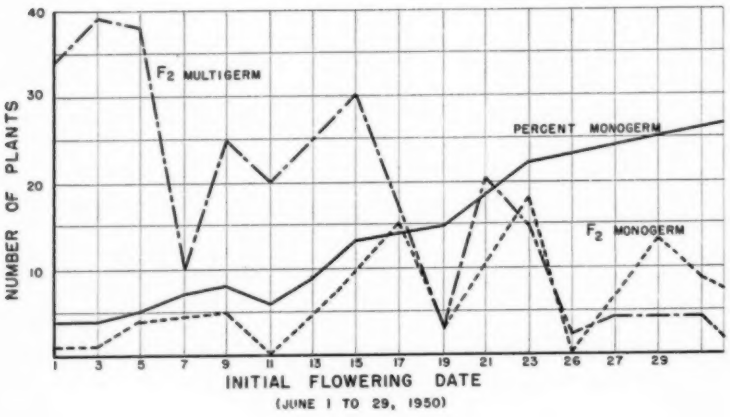

Figure 2.

segregates flowered very late. The majority of the monogerm F_2 plants flowered late and only a small proportion of these flowered early (Figure 2). The F_2 offspring were classified into four classes: multigerm early, multigerm late, monogerm early and monogerm late (Table 5). Assuming an independent single dominant gene for early flowering, the expected and observed number of plants did not coincide in all four classes. The parental classes, multigerm early and monogerm late, were in considerable excess. The two new classes, multigerm late and monogerm early, accounted for by genic recombination, contained fewer plants than expected. Therefore, the monogerm character is linked with a gene responsible for a late-bolting tendency and late flowering. The linkage intensity in F_2 was calculated to be 25.3 $\pm$ 1.86 percent for a field experiment in 1950 and 25.8 $\pm$ 1.43 percent in 1951. The linkage intensity for a backcross population was calculated to be 34.2 $\pm$ 3.46 percent for a test in the greenhouse (Table 5) (3, 4).

A similar linkage was observed in hybrids between monogerm beets and an annual beet from California which grows wild near San Jose. When F_2 hybrid seed from the cross, multigerm California annual beet x monogerm SLC 101, was planted June 21 at Salt Lake City, some of the annual plants started to bolt in July. But most of these early bolters were multigerm and by August 25 only five percent of them appeared to be monogerm. Then the percentage of monogerm plants increased gradually, reaching 10.3 percent at the end of October. The enormous deficiency of monogerm plants by October indicates that most of the potential monogerm segregates did not flower during the first year. Unpublished results obtained by F. V. Owen indicate that the late-bolting tendency in SLC 101 is not allelic to the gene *B* for bolting described by Abegg (1, 5, 6) and obtained from Munerati's annual beet, but by another allelomorph which is directly related with bolting tendency in biennial beets. The inbred line SLC 101 represents a very valuable breeding stock for development of non-bolting varieties for such areas as California where fall or winter plantings are made for commercial sugar beet production.

Summary

When the monogerm race SLC 101 was crossed with multigerm beets, the multigerm character was dominant in F_1 hybrids, but the dominance was not complete. In F_2 populations derived from hybridization of SLC 101 with multigerm sugar beets, red table beets, fodder beets and Swiss chard, a 3:1 ratio was observed for segregates with multigerm versus monogerm fruits.

The monogerm character is produced by one recessive basic gene in the homozygous *mm* condition. Some other genes may modify the manifestation of the gene *m* causing the appearance of a few double-germ fruits on the monogerm plants.

Gene *m* was linked with a gene causing late-bolting tendency. The linkage intensity in F_2 was calculated to be 25.3 $\pm$ 1.86 in 1950 and 25.8 $\pm$ 1.43 in 1951.

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Selective Fertilization Studies and Recovery of Self-sterile from Self-fertile Races of Monogerm Sugar Beets

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Introduction

All contemporary sugar-beet varieties are self-sterile. Introduction of self-fertile monogerm races into self-sterile populations may lead, in greater or less degree, to selfing within the hybrid populations and will result in a decrease in vigor and productivity. Obtaining self-sterile monogerm races makes it possible to develop monogerm varieties by the simplest method, namely, the crossing of the best commercial self-sterile varieties with self-sterile monogerm races.

Selective Fertilization in SLC 101

The original monogerm race SLC 101 is self-fertile. Selective fertilization favors the plant's own pollen. There was an average of 17.08 percent hybridization under open-pollination when single plants of SLC 101 were grown within large multigerm populations at Salt Lake City, Utah, (Table 1). Deviations were observed from 3 to 28 percent in separate cases. Selective fertilization with respect to the plant's own pollen was also observed in field plantings in Oregon and California (22.81 percent hybridization) and also when these monogerm plants were grown in greenhouses (15.52 percent hybridization). In a total of 5,904 plants, 953 hybrids (16.14 percent) were observed.

When the self-fertile monogerm race SLC 101 was crossed with self-sterile multigerm varieties, all F_1 plants were observed to be self-fertile. In agreement with the oppositional hypothesis (1)[2] F_2 hybrids were also self-fertile when derived from F_1 plants by selfing under paper bags. Of about 300 monogerm F_2 plants derived from controlled self-pollination of F_1 plants, only two were self-sterile (it is questionable whether the apparent self-sterility of these plants was due to their genotype or to some other cause). All F_3 monogerm plans also appeared self-fertile. Attempts to obtain self-sterile monogerm beets without preliminary selection for self-sterility were unsuccessful.

Outline of Methods of Obtaining Self-Sterile Monogerm Races.

The method of obtaining self-sterile monogerm races was based upon genetic studies and upon embryological investigations. (A). It was necessary to produce backcross generations (multigerm self-sterile plants x F_1) to obtain segregation for self-sterility and self-fertility. (B.) It was necessary to select self-sterile plants from the first backcross generation (b_1) and monogerm plants in the succeeding generation (b_1)$_2$. (C.) It was necessary to distinguish self-sterile plants from self-fertile plants on the basis of fruit and ovule development at the time of flowering (2).

If self-sterility versus self-fertility is controlled by one allelic series of genes (1) and the multigerm versus monogerm characters by another independent pair of genes (3), then the b_1 progeny must consist of four genotypes: *MM* $Sf S^1$, *Mm* $Sf S^1$, *MM* S^1S^2, and *Mm* S^1S^2 (S^1 and S^2 indicating

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[2] Numbers in parentheses refer to literature cited.

allelic genes for self-sterility). All plants in b_1 must be multigerm; 50 percent of them are expected to be self-sterile and 50 percent self-fertile. The self-sterile and self-fertile groups will both segregate in the next generation for monogerm plants.

Table 1.—Percent Hybridization in Offspring from SLC 101 Grown Under Open-polination With Other Varieties.

Location of seed isolation	Lines studied	Plants	Hybrids
	Number	Number	Percent
SALT LAKE COUNTY			
Bateman	2	405	27.91
Shaw	4	551	21.63
Turner	2	509	20.23
Jordan	2	288	20.48
Hastings	2	134	19.40
Atkinson	2	421	15.67
Young	2	333	12.31
Hamblin	2	493	9.54
Christensen	2	456	7.45
D. Turner	2	279	3.22
Total	22	3,869	17.08
GREENHOUSES IN UTAH			
Ogden	6	463	23.97
Intermountain	2	108	27.77
Sugarhouse	5	762	8.66
Total	13	1,333	15.52
OTHER LOCATIONS			
Ogden, Utah	7	222	16.21
Salem, Oregon	3	174	38.50
Salinas, California	6	306	13.72
Total	16	702	22.81
Grand total	59	5,904	16.14

If b_1 populations, consisting of self-sterile and self-fertile plants, are propagated under open pollination, we can expect (without much error) that all self-fertile plants will be selfed and all self-sterile plants will be pollinated by pollen from both self-sterile and self-fertile plants in proportion to the respective pollen production in the populations. In this case the genetic composition of the progeny in a large population will tend to approach the ratio 76 *MM*:40*Mm*:12*mm* (Table 2). In other words, 12 monogerm plants will occur to 116 multigerm. This gives 9.37 percent monogerm plants in the population. Of these monogerm plants 75 percent must be self-fertile and only 25 percent self-sterile. This means that only one self-sterile monogerm plant will appear to 41.6 other plants.

To increase the number of self-sterile monogerm plants in the $(b_1)_2$ generation, it is necessary to select self-sterile b_1 plants. For this purpose, part of the inflorescences of each b_1 plant must be enclosed in a paper bag. Two or three weeks later after initiating of flowering, depending on temperatures, the self-sterile plants can be distinguished and selected. Further work with self-sterile plants can be conducted in four different ways (Table 2).

1. Propagation of b_1 self-sterile plants by crossing *inter se*.
   a. The group of selected self-sterile plants can be isolated and left

for open-pollination. All self-fertile plants must be discarded beforehand.

b. After the seed is harvested, the selected self-fertile plants can be saved for seed production in an isolated group the next year. They can also be propagated vegetatively and clones can be grown to produce seed under open-pollination. In all these variations of procedure, the groups of self-sterile plants are isolated from self-fertile plants in the population. Therefore, the genetic composition of the progeny in $(b_1)_2$ will differ from the preceding population. The composition of the population in this case will have a tendency to approach the ratio $9MM{:}6Mm{:}1mm$ (Table 2). The ratio of multigerm to monogerm plants will approach 15:1. Only 6.25 percent of the plants in the population will be monogerm, but all these will be self-fertile. No other method gives such possibilities.

c. If it is difficult to isolate the selected self-sterile plants as a whole group under open pollination, they can be crossed with each other by exchanging paper bags. By exchanging paper pollinating bags between self-sterile b_1 plants, 50 percent of the crosses will be lost as far as self-sterile monogerm offspring is concerned, because there is a 1:1 chance for self-sterile *MM* plants.

Table 2.—Recovery of Self-sterile Monogerm Beets from Hybrids from the Monogerm Race SLC 101 *(mm SfSf)*, Expected Segregation[1] in $(b_1)_2$ Generation.[2]

Utilization of 1st backcross—b_1	Genotypes *MM:Mm:mm*	Phenotypes *M:m*	*mm* segregates			Crosses lost Self-sterile *Mm* hybridized under paper bags
			Total	Self-sterile to remainder		
	Ratio:	Ratio:	Percent	Percent	Ratio:	Percent
b_1 x b_1 (no discards)	76:40:12	116:12	9.37	25	1:41.6	....
b_1 x b_1 (self-fertiles discarded)	9:6:1	15:1	6.25	100	1:15	50[3]
b_1 x F_1 *Mm* self-sterile	6:8:2	14:2	12.5	50	1:15	....
b_1 self-sterile x F_2 *mm*[5]	0:12:4	12:4	25.0	25	1:15	50[4]

[1] No linkage assumed between gene Sf for self fertility and gene *m* for monogerm fruits.

[2] b_1 = first backcross to multigerm $MM\ (MM\ SfS^3 + Mm\ SfS^1 + MM\ S^1S^2 + Mm\ S^1S^2)$. $(b_1)_2$ = generation after b_1.

[3] Crosses considered lost which do not yield monogerm *mm* beets in the next generation.

[4] Crosses considered lost which do not yield self-sterile monogerm *mm* beets in the next generation.

[5] With regard to the gene *Sf* for self-fertility, 50 percent of the F_2 *mm* beets are homozygous and 50 percent are heterozygous.

2. The self-sterile plants selected in b_1 can be pollinated by pollen from F_1 hybrids derived from crosses of monogerm beets of SLC 101 with any valuable self-sterile multigerm variety. The genotypic composition of the progeny will approach $6MM{:}8Mm{:}2mm$ (Table 2) in the next generation. Multigerm to monogerm plants will occur in the ratio of 14:2. The percentage of monogerm plants will increase to 12.5 percent and of these monogerm plants 50 percent will be self-sterile and 50 percent will be self-fertile, but the self-fertile will be heterozygous for the genes controlling self-fertility and self-sterility. None of the crosses will be lost by using this method because the male parent is heterozygous for both genes.

3. Selected self-sterile b_1 plants can be pollinated by pollen from new monogerm plants derived from F_2 hybrids. These F_2 monogerm *mm* plants contain two genotypes: those heterozygous for self-fertility, SfS^1, SfS^2 etc., and homozygotes *SfSf*. Progenies derived from these crosses will segregate in the next generation with a ratio approaching 12*Mm*:4*mm* (Table 2). Four monogerm plants will appear to 12 multigerm. The proportion of monogerm plants will increase to 25 percent, but three-fourths of these monogerm plants will be self-fertile because they carry the gene for self-fertility in the heterozygous condition and only one-fourth of them will be self-sterile. Of the crosses derived from self-sterile *Mm* b_1 plants 50 percent will be lost by pollination to F_2 *mm* pollinators because 50 percent of the male parents are homozygous for the gene *Sf*. The ratio of self-sterile monogerm plants to all other plants in the population will be 1:15, the same as by the first and second methods.

4. Another method of developing self-sterile monogerm races consists of crossing monogerm F_2 plants with multigerm self-steriles. The gametes expected from these monogerm F_2 plants will be 3*m* Sf: 1*m* S^1, (or S^2, S^3, etc.). When plants from multigerm self-sterile varieties are pollinated by pollen from monogerm F_2 plants, 25 percent of the F_1 hybrids will be self-sterile and multigerm *Mm* (S^1S^2, S^2S^3 etc.). Isolation and propagation under open-pollination of this group of self-sterile *Mm* plants in the next generation will produce 25 percent monogerm self-sterile plants.

Experimental Results

Plants in the first backcross generation (b_1) were bagged and checked for self-sterility versus self-fertility. Segregation for self-sterile and self-fertile plants followed a 1:1 ratio (80 self-steriles: 77 self-fertiles). Self-sterile plants were selected. The most practical methods of obtaining progeny from selected self-sterile b_1 plans which produce a comparatively high percentage of self-sterile monogerm plants appeared to be as follows: 1. exchanging of paper bags on selected self-sterile plants, and 2. obtaining seed under open-pollination from other branches of these plants. Because of a larger amount of seed more self-sterile monogerm plants can be selected in the offspring from open pollinations.

Offspring obtained in 1950 from crosses between self-sterile b_1 plants with F_1 hybrids and from open pollination of self-sterile plants were transplanted in 1951 to the Amalgamated Sugar Company greenhouse at Ogden, Utah, and to the greenhouse at Salt Lake City and also to overwintering plantings. In all plantings multigerm segregates were discarded and all monogerm beets were bagged to determine whether they were self-fertile or self-sterile.

Progenies derived from open pollination of self-sterile *Mm* plants showed good results, which were equal to those obtained by pollination of these *Mm* plants by F_1 pollen. From progenies derived from open pollination at Salt Lake City there were 9 percent monogerm *mm* segregates of which 48 percent appeared to be self-sterile. From eight overwintered lines two produced a sufficient number of monogerm plants so that the

segregation could be observed. In these lines the self-sterile monogerm beets accounted for 49.3 percent of all the monogerm segregates. From a total of 76 monogerm segregates 37 were self-sterile and 39 self-fertile.

A total of 78 self-sterile monogerm beets was selected from several thousand hybrid offspring in 1951. These self-sterile monogerm beets were crossed *inter se* by exchanging bags. Their progenies will be checked in 1952 to confirm whether or not they are self-sterile as expected. The first self-sterile monogerm elite seed will be obtained from this material.

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Methods and Results of Breeding Work With Monogerm Beets

V. F. SAVITSKY[1]

Introduction

This report is based on a study of the inheritance of the monogerm character and a study of hybrids derived from the original monogerm line SLC 101. Introduction of monogerm sugar beets into commercial use will decrease the quantity of seed used for planting, but will increase requirements for improved seed quality. The quality of monogerm seed can be improved significantly by sorting and cleaning machines. Demands which will be made for improved size and weight of monogerm seed and for increased vigor of seedlings will make it necessary to develop the most appropriate agronomic methods for seed production which will produce seed of the highest quality. However, the main problems in this field must be solved by breeding work.

Variability of Absolute Weight of Monogerm Fruits and Breeding Work with this Character

Different varieties of *B. vulgaris* L. are not distinguished very much by size and quality of fruits, but large variations in fruit or seed-ball characters are manifest within each population. Therefore, inbred lines and clones originating from the same variety are very diverse for seed characters (3).[2]

In all beet varieties, the weight of seed-balls increases in proportion to the number of flowers in the flower cluster which goes to form the seed-ball. The coefficient of correlation for these two characters varies within populations from 0.4 to 0.7. The same correlation was observed for different plants within a clone. Environment can modify both of these characters. The intervarietal and inter-biotypical correlation makes breeding work very difficult for size of fruits and seedlings in multigerm beets. The study of inheritance and variability of the weight of fruits is facilitated now because of the new monogerm beets.

The pronounced correlation between number of flowers per flower cluster and weight of seed-balls for F_2 multigerm segregates derived from five different crosses between multigerm and monogerm beets is illustrated in Figure 1. These F_2 multigerm segregates from the five different crosses also showed different average weights per 1,000 seed-balls, even when the number of flowers per flower cluster was the same (Figure 1).

The variability of the weight of fruits in monogerm beets differs from the variability in multigerm plants. Because of the correlation between number of flowers per seed-ball and the weight of seed-balls in multigerm beets, one might expect that monogerm plants would develop very small fruits. In fact, the weight of 1,000 seed-balls from multigerm beets was on the average two grams more than the weight of 1,000 monogerm fruits from

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[1] Collaborator, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, in cooperation with the Curly Top Resistance Breeding Committee.

[2] Numbers in parentheses refer to literature cited.

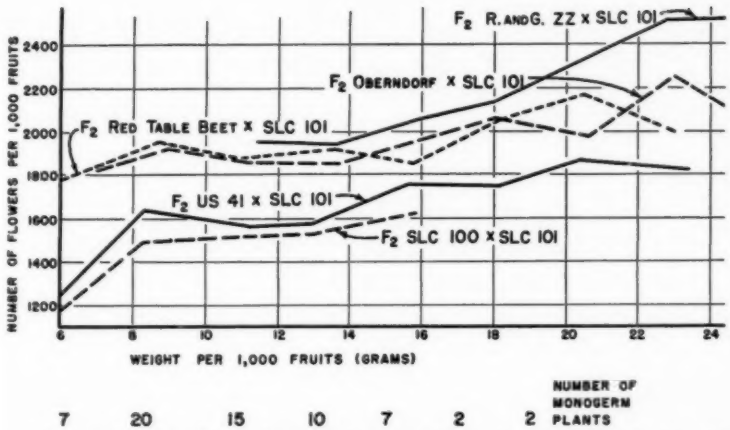


Figure 1.—Correlation between number of flowers per flower cluster and weight of 1,000 seed-balls in multigerm F_2 segregates from five different F_2 populations. The same five F_2 populations also produced 63 monogerm segregates. A frequency distribution showing the weight of 1,000 seeds from each of these 63 beets is shown at the base of the figure.

the same five F_2 populations (Table 1). The coefficient of variation for the weight of 1,000 fruits from different F_2 monogerm plants was 14.9 percent; for the multigerm segregates from the same population this coefficient was a little lower, 13.9 percent. Because of the larger variability of the weight of fruits in the monogerm F_2 segregates, the amplitude of their variation approaches the amplitude of variation for the weight of 1,000 seed-balls in multigerm beets. Therefore, individual monogerm races can develop large as well as very small fruits. In F_2 populations segregating for multigerm versus monogerm plants, the majority of monogerm plants was found to produce small fruits (Table 1). Selection of monogerm plants for size of fruits in F_2 and F_3 is possible and is necessary since in 1951 experiments the weight of 1,000 fruits of monogerm plants varied from three to 34 grams. In spite of large variability in fruit weight from different genotypes, the weight and size of monogerm fruits from one monogerm plant or inbred line were more uniform than the same properties of fruits from multigerm beets. The uniformity of fruits on double-germ beets was

Table 1.—Weight of 1,000 Fruits in Monogerm and Multigerm F_2 Segregates (SLC 101 x Multigerm Beets).

	Classification of F_2 plants on average weight per 1,000 fruits (in grams)										
F_2 segregates	4 g.	6 g.	8 g.	10 g.	12 g.	14 g.	16 g.	18 g.	20 g.	22 g.	Total plants
	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	Number
Monogerm plants	3	4	20	15	10	7	2	2			63
Multigerm plants		9	22	43	39	36	20	13	4	1	187
Total plants	3	13	42	58	49	43	22	15	4	1	250
	%	%	%	%	%	%	%	%	%	%	
Monogerm plants	100	31	48	26	20	16	9	13	0	0	

intermediate to the uniformity in mono- and multigerm plants. This can be explained by the differences in the values of the coefficient of variation for the number of flowers per flower cluster. In multigerm beets this coefficient was found to be 31 percent; in double-germ races it decreased to 20 percent because double-germ plants produce some monogerm fruits and some fruits with three flowers.

An experiment in 1949-1951 showed that selection for weight of fruits was successful in multigerm as well as in monogerm beets. Selection can be based on the size of fruits (diameter or weight of fruits) and on the type of inflorescence. The latter makes it possible to select plants before flowering.

Breeding work for increased weight and size of fruits can contribute towards increased tonnage. The best backcross hybrids which produced high yield were obtained when the recurrent multigerm parent was selected for size of seed and for a particular type of inflorescence.

Selection for size of fruits among monogerm F_2 segregates showed that 92.8 percent of the selected inbred monogerm S_2 lines showed good germination and seedling vigor in the field. About 10 percent of the selected inbred lines were low in germination percentage and seedling vigor. It may be as well to accompany selection for weight of fruits by a study of seedling vigor in laboratory tests.

Selection for improved size and quality of monogerm seed should be made in the first hybrid generations when the monogerm segregates are selected.

Development of monogerm varieties can follow different breeding methods, descriptions of which follow.

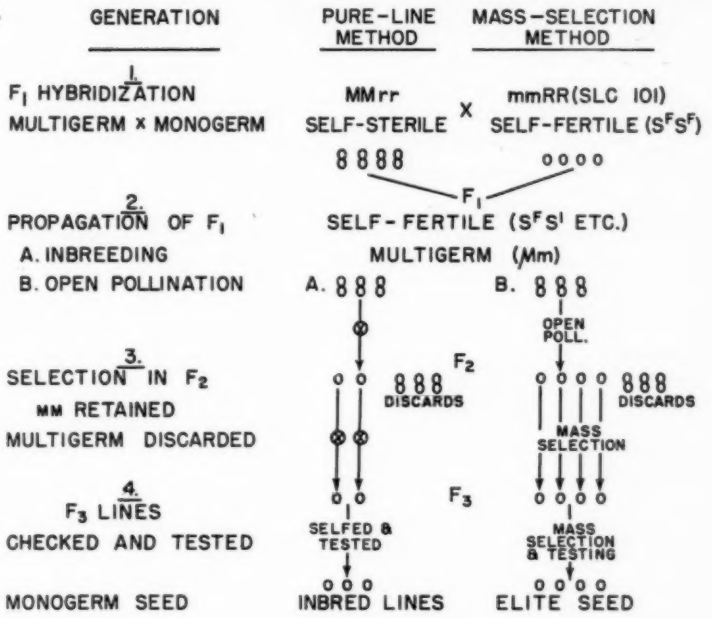
Method of Obtaining Monogerm Varieties from F_2 and F_3 Lines

The simplest way to obtain monogerm varieties is directly from F_2 and F_3 lines (Figure 2) as follows: Crossing of valuable multigerm varieties with the monogerm race, open pollination or selfing of F_1 hybrids, and selection for monogerm segregates in the F_2 generation. It has been assumed advisable to plant seed from each monogerm plant separately for critical tests. Elite monogerm seed is obtained from a mixture of the progeny of the best F_3 lines. Selection of monogerm plants in the F_2 generation is also suitable when inbred lines from selected plants are developed and commercial seed showing heterosis is raised from these lines.

Selection of monogerm beets in the F_2 generation will acquire still larger significance when not only self-fertile, but also self-sterile, monogerm beets can be used in the breeding program. Then in two or three generations mass and individual selection will make it possible to obtain new monogerm varieties.

The Backcross Method

The American as well as the European sugar industry needs many different varieties which are resistant to different diseases, which are adapted to different climates and different agricultural conditions. In all these varieties the multigerm fruits must be changed to monogerm. This enourmous work can be accomplished by using the backcross method.



DESIGNATIONS:

8 = (MM OR Mm) = MULTIGERM
o = mm = MONOGERM
S^1, S^2---S^N = GENES FOR SELF-STERILITY
S^F = GENE FOR SELF-FERTILITY (ALLELIC TO S^1, ETC.)
R = DOMINANT GENE FOR RED HYPOCOTYL COLOR
r = RECESSIVE GENE FOR LACK OF RED COLOR
⊗ = SELF-POLLINATED UNDER PAPER BAGS

FIGURE 2.

OBTAINING MONOGERM VARIETIES FROM F_2 AND F_3

When only sugar-beet varieties (not red table beet or fodder beets) are involved in the breeding work, usually one or two backcrosses are sufficient. Hybridization of SLC 101 with different varieties showed that even the first backcross formed very valuable populations for selection of monogerm plants. When curly-top-resistant varieties were involved in the crosses, the degree of curly-top resistance in b_1 populations nearly approached the level of resistance of the highly resistant varieties. The same b_1 populations showed good yield and sugar percentage when the multigerm par-

ents were luckily combined. The b_1 generation is also the most suitable generation for selection of self-sterile beets as shown in experiments of Dr. H. Savitsky (2).

A further increase in the number of backcrosses complicates the selection of monogerm plants as well as selection for sugar percentage and yield. In a self-sterile population the percentage of monogerm segregates drops from 6.5 to 1.56 when reproductions are made from the first and second backcross generations respectively. It is better to make the second backcross to multigerm beets when necessary after monogerm plants have been selected in the $(b_1)_2$ generation (Figure 3). This scheme can be applied also to the development of monogerm varieties for resistance to curly top and also for the development of self-sterile monogerm varieties.

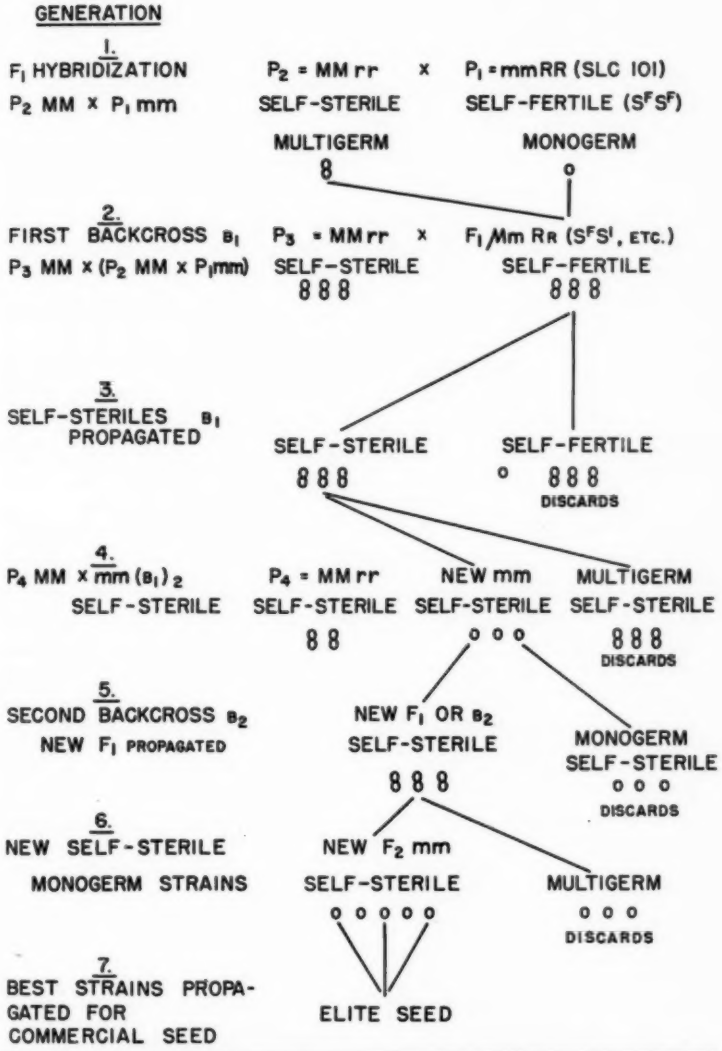
Selection for self-sterile plants should be started in the first backcross generation (b_1), and self-fertile plants discarded. It might be well to harvest the seed from self-sterile b_1 plants separately, because only 50 percent of these plants will carry the gene *m* in the heterozygous condition. In the next generation the self-sterile plants will segregate for monogerm and multigerm beets. The latter must be discarded before flowering.

The monogerm plants selected for self-sterility in the $(b_1)_2$ generation to be crossed under open pollination should be grown adjacent to a multigerm pollinator. This is the second backcross. An examination for self-sterility of the selected plants may be made in the next generation; only hybrid multigerm plants will be retained for further work. These plants will segregate in the next generation for multi- and monogerm self-sterile plants. Seed from these new self-sterile monogerm plants must be harvested separately. A mixture of seed from the best monogerm lines will give elite seed by this method in six or seven generations. This seed represents the product of two-fold selection and two-fold backcrossing.

Inbreeding and Heterosis

The inbreeding method is very valuable for incorporation of genes responsible for new properties (non-bolting tendency, resistance to disease, size of fruit, desirable shape of root, etc.) and also for making use of the effect of heterosis. Self-fertile monogerm inbred lines in the S_3 to S_5 generation of selfing derived from hybrids with SLC 101 can be utilized for:

1. building a population from a mixture of the best inbred lines which can partially intercross under open pollination; 2. development of special male-sterile inbred races and two types of pollinators for them. The first pollinator must be an inbred line of type 0 (1) in order to produce completely male-sterile offspring. If this line is uniform, the male-sterile line in a few generations of backcrosses will become more or less equivalent to the hermaphrodite line. The second pollinator may be used to obtain commercial seed. Any multigerm or monogerm beets, inbred lines, varietal populations, F_1 hybrids or triple hybrids, may be used as a second pollinator; the only requirement is that it produce heterosis when crossed to the male-sterile line. The majority of the contemporary varieties and inbred lines do not belong to type 0. Dr. F. V. Owen's investigations indicated that SLC



OBTAINING SELF-STERILE MONOGERM STRAINS AND VARIETIES BY THE BACKCROSS METHOD
(FOR DESIGNATIONS SEE FIGURE 2.)

FIGURE 3.

101, when crossed with different varieties, can produce F_2 plants belonging to type 0.

If the male-sterility method is used in the breeding program with monogerm beets, it is necessary to develop two types of hybrids at the same time: 1. backcrosses to male sterile to obtain male-sterile monogerm races, and 2. hybrids to obtain monogerm pollinators which can give 100 percent male sterility in the progeny of MS plants during their propagation. The male-sterile monogerm beets must produce good fruits, because these fruits represent commercial seed.

Summary

The effectiveness of breeding work with monogerm beets by any breeding method depends upon genetical diversity for valuable properties in the initial material used in the breeding program. The large genetic diversity in the species *B. vulgaris* L. opens up new perspectives for improvement of sugar percentage, tonnage, quality of seed, vigor of seedlings, etc., simultaneously with breeding for the monogerm character.

These comprehensive methods have been used in breeding work with hybrids derived from crosses of the monogerm beet SLC 101 with different sugar beets, red table beets, fodder beets and Swiss chard. Many new inbred lines and populations of monogerm beets were obtained as a result of this work. These new monogerm strains showed a large variation in size and type of fruits, in earliness of bolting tendency, in sugar percentage and tonnage. Curly-top-resistant monogerm strains were selected among them. Dr. F. V. Owen obtained male-sterile monogerm strains and Dr. H. Savitsky developed self-sterile monogerm beets. The writer obtained beets in which the monogerm character was combined with characters of red table beets, fodder beets and Swiss chard. The presence of diverse types of monogerm beets now makes it possible to start breeding work within monogerm strains by applying different breeding methods.

Every sugar-beet breeding station must have at its disposal, in addition to self-fertile monogerm beets, also 1. monogerm beets resistant to the main diseases of the area, 2. male-sterile monogerm beets and appropriate pollinators for them, and 3. self-sterile monogerm beets. Transference to all sugar-beet breeding stations of these new breeding stocks will help them to expedite the development of new monogerm varieties.

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Inbred Seed Production in Progeny Classification For Type O Plants in Open-Pollinated Varieties

DONALD F. PETERSON[1]

A large number of self-pollinations in normally self-sterile open-pollinated varieties was made at Sheridan, Wyoming, in the seasons of 1950 and 1951. These self-pollinations were made at the same time that the individual plants were crossed to male sterile plants in an effort to identify type O segregates in the population. It was hoped that the S_1 plants which would subsequently be classified as type O could be maintained by self-pollination. The purpose of this paper is to report on the seed production of these self-pollinated plants as well as the F_1 progenies classified as type O.

Procedure

Approximately 800 roots of MW 381, a non-resistant type, and 200 roots of 40308-0, a leaf-spot-resistant type, were planted in the field in the summer of 1950. Roots produced from seed harvested from open-pollinated male sterile plants from these same two varieties were planted in the same field in such a manner that male sterile roots of MW 381 would be in a row adjacent to the normal pollen-producing plants of MW 381, and likewise for the variety 40308-0. The male sterile segregates in alternate rows were then used as female parents in crosses with the pollen-producing plants from adjacent rows. Three white bleached Kraft paper bags were placed on each pollen-producing plant and all male sterile plants were bagged as heavily as possible. When the flowers on the male sterile plants had opened sufficiently (about two weeks after bagging), one of the bags from the male parent was removed and immediately replaced with a new bag. A bag was then removed from a male sterile plant and replaced with the pollen containing bag from the pollen parent. Thus, for each F_1 seed lot produced, using one bag exchange, a total of three bags was used to produce self-pollinated seed of the male parent involved in the cross.

In the variety MW 381, 717 crosses and selfs were made, 674 of which produced enough seed of both types to be planted for steckling production. In the variety 40308-0, 189 crosses were made and seed lots of 174 crosses and selfs were obtained in sufficient quantity to be planted. Seed lots were planted only when there were at least two grams of the F_1 seed and at least .1 of a gram of inbred seed. The amount of inbred seed ranged from 0 to as much as 38 grams per lot.

All seed lots were planted at Phoenix, Arizona, in the fall of 1950. The stecklings produced there were harvested in January of 1951, shipped to Sheridan, Wyoming, for thermal induction in the root cellar and then transplanted to the field in the spring. Plantings were made in such a manner that the inbred line stecklings were placed with their related F_1 progenies, so that those progenies classified as 100 per cent male sterile could be backcrossed to the inbred line.

Results

It was expected that a portion of the inbred seed produced would not be viable; therefore, rather than report inbred seed produced by weight or number of seed balls, it was decided to report the number of plants actually

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produced from each lot of inbred seed. Table 1 divides the number of inbred seed lots according to the number of plants produced in intervals of five plants each. Percentage values for each class are also given.

Table 1.—Inbred Seed Lots Produced at Sheridan, Wyoming, in 1950 Grouped According to Number of Plants Produced at Phoenix, Arizona, in the Winter of 1950-51.

	Number of Plants Produced								
Variety	0	1-5	6-10	11-15	16-20	21-25	26-30	Over 30	Total
MW 381	78	88	128	163	121	58	28	10	674
%	11.6	13.0	19.0	24.2	18.0	8.6	4.2	1.4	100
40308-0	15	33	42	40	30	9	3	2	174
%	8.0	19.0	24.1	23.0	17.2	5.2	1.7	1.2	100

In the variety MW 381, 78 seed lots, or 11.6 percent, of the total seed lots planted, failed to produce plants to carry on the line. The percentage figure for variety 40308-0 was 8 percent. Approximately 90 percent of the inbred seed lots produced plants to perpetuate the line. It is realized that some of the plants produced, especially where only one or two plants were obtained from a lot of seed, may have resulted from off pollinations. However, on the chance that they were true selfs, these single plants were carried along and used where completely male sterile progenies were found.

All F_1 progenies were classified for pollen production. No attempt was made to identify the number of semi-male steriles in segregating populations. Only those progenies which were 100 percent male sterile were marked and then backcrossed to their respective inbred parents. In Table 2 the number of progenies completely male sterile are grouped according to the number of selfed plants produced by the paternal inbred line.

Table 2.—Number of F_1 Progenies Classified as 100 Percent Male Sterile at Sheridan, Wyoming, in 1951.

	Number of S_1 Plants								
Variety	0	1-5	6-10	11-15	16-20	21-25	26-30	Over 30	Total
MW 381	—	5	7	6	7	2	1	1	29[1]
40308-0	—	3	6	12	6	—	—	—	27[2]

[1] Out of a total of 674, or 4.3%
[2] Out of a total of 174, or 15.5%

Of the 674 MW 381 F_1 progenies planted, 29, or 4.3 percent, were classified as 100 percent male sterile. Of the 174 40308-0 F_1 progenies planted, 27, or 15.5 percent, were classified as completely male sterile. It was expected that a much larger number of type O plants would be found in the 40308-0 line because male sterile plants occurred in greater number in the open-pollinated isolation where seed of the open-pollinated male sterile plants was obtained. Since no F_1 groups were planted where selfed plants were lacking, there were, no doubt, a few lines lost which may have been type O. This figure would probably be near the 10 percent value of the O column (where no plants were obtained) of Table 1.

In 1951 the same procedure described above was used in producing 756 F_1 and S_1 lots of seed involving 12 different varieties as pollen parents. One exception was that in 1951 the male sterile parent used in all crosses was SL 6106, which is highly male sterile. In addition, 348 crosses were produced

involving the 56 F_1 progenies, identified as completely male sterile, backcrossed to their respective paternal parent inbred lines. Because of the small size and necessarily close spacing of these plants, only one bag could be placed on each plant—both F_1 and S_1 types. The S_1 plants were again selfed to produce S_2 seed. Again, all this material was planted at Phoenix, Arizona, this fall for steckling production.

Stand counts on the S_1 and S_2 line lots of seed which contained five plants or less were made and are summarized in Table 3.

Table 3.—Number of Plants Produced at Phoenix, Arizona, from 1,104 Lots of Inbred Seed Produced at Sheridan, Wyoming, in 1951.

	Number of Plants			
	0	1-5	More than 5	Total
S_1	103	95	558	756
%	13.6	12.6	73.8	
S_2	94	89	165	348
%	27.0	25.6	47.4	

In Table 3 it is readily seen that S_1 seed lots producing no plants in 1951 were 13.6 percent of the total and that this figure compares favorably with the average of 10 percent in 1950. Nearly 90 percent of the S_1 self-pollinations produced plants to perpetuate the line. The results obtained with the S_2 seed were not nearly as good since 27 percent of the lots failed to produce plants.

This is probably due to two factors: First, since the stecklings planted were very small and were planted close together as compared to the larger-sized roots and wide spacing of the plants used for S_1 seed production, only one bag could be placed on each plant. Second, in order to spread out the pollinating season, the S_2 stecklings were planted at a later date than the S_1 roots. Thus, the pollinations were made when the mean temperatures were higher, which may have accounted for lower seed set.

However, it is gratifying to note that, of the 56 original F_1 completely male sterile progenies, only four were completely lost because of the failure to obtain S_2 seed to carry on the line.

It would seem then that under environmental conditions similar to those at Sheridan, Wyoming, type O plants isolated in self-sterile varieties may be maintained by self-pollination.

Summary

A total of 848 self-pollinations in two varieties was made at Sheridan, Wyoming, in 1950. Approximately 90 percent of these self-pollinations produced seed which gave rise to a varying number of plants. The same number of F_1 crosses between male sterile plants and the plants which were selfed were classified for pollen production and a total of 56 were identified as being entirely male sterile.

In 1951 a total of 756 self-pollinations in twelve varieties was made. Again, 87 percent of these self-pollinations produced seed which produced plants. In addition, 348 S_2 self-pollinations were made in connection with a series of backcrosses. Of this group, 73 percent produced viable seed. This lower figure is probably due to time and manner of planting.

Sugar Percent in Progenies Derived from Hybrids to Monogerm Sugar Beets

G. K. Ryser and V. F. Savitsky[1]

The monogerm inbred SLC 101 is a necessary component in breeding work for the incorporation of the monogerm character for the immediate future. It is important in breeding work with inbred lines to study combining ability of the line and the pecularities of segregation when the given line is crossed to other varieties. Characteristics of an inbred line, based upon study of F_1 and F_2 hybrids derived from it, can give more important indications of inherent possibilities than the characteristics of the line itself. Such a study of an inbred line may be made when the line is relatively uniform.

Sublines derived from selfing SLC 101 for three generations showed that SLC 101 is relatively uniform for type of flowers, fruits and inflorescences, also for type of roots and foliage. SLC 101 appeared to be homozygous with respect to genes for many morphological characters and for self-fertility. This uniformity indicates that SLC 101 had probably been selfed for at least four to seven generations under open pollination before it was found in 1948 (6).[2]

Because of the genetic uniformity of SLC 101, a study of its F_1, F_2, F_3 hybrids and backcross populations makes possible some predictions as to performance in new F_1, F_2 and backcross hybrids. These hybrids are also important for further selection work. Breeding for the monogerm character and for disease resistance is discussed in other papers (3 and 5).

Material and Methods

All F_1 hybrids with SLC 101 were obtained by pollination of self-sterile multigerm beets with white hypocotyl color rr (4) by pollen from SLC 101. SLC 101 is homozygous RR for red hypocotyl color and when white rr self-sterile plants were used, all F_1 hybrids were heterozygous reds (Rr). A description of all the varieties used is shown in Table 1. F_2 populations were obtained by self-pollination of F_1 plants under paper bags and by open pollination. F_1 hybrids derived from crosses of the multigerm varieties with SLC 101 were planted in isolations for propagation. In a preliminary test, single rows of four F_2 populations and nine b_1 populations were grown at Granger, Utah, in comparison with the commercial variety US 22/3 (Table 2). Each row was divided into three equal lengths for harvest data, and an estimated precision of the experiment is shown in Table 2. No injury from curly top was observed.

Sucrose percentage and purity determinations (six samples for each hybrid) were made at the Salt Lake City Station under supervision of C. H. Smith. A portion of the leaded filtrate from each sample was preserved at about 40° F. and from this a sodium determination was made later by Myron Stout and C. H. Smith by use of the Amalgamated Sugar Company's spectrophotometer at Ogden, Utah.

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[2] Numbers in parentheses refer to literature cited.

Table 1.—Description of Varieties.

Variety and S. L. Number	Description
SLC 101	Self-fertile monogerm inbred
US 22/3	Commercial curly-top-resistant variety
US 75	Non-bolting curly-top-resistant variety
US 216	Leaf-spot-resistant high-sugar variety
Klein E	Kleinwanzleben E yield type from Germany—also known in U.S.A. as R. and G. Old Type
Klein ZZ	Kleinwanzleben ZZ, an extreme sugar type from Germany
Lanker	Fodder beet variety from Germany
Ovana	Otoftegaard, half-sugar fodder beet from Denmark
Red table beet	Extra early Egyptian red table beet from W. Atlee Burpee Company
SL 83-3	Refers to selections for large seed balls with elongated inflorescence from SL 941
SL 824	A high sugar curly-top-resistant variety, also known as US 35/2
SL 92	A yield-type variety very high in curly-top-resistance, selected from US 22/3
SL 941	An F_2 from the high-sugar variety US 35 x US 22/3

Experimental Results

Variation in Sugar Percentage in F_2 Populations

SLC 101 when hybridized with a range of multigerm varieties produced very distinct F_2 populations. The F_2 populations derived from hybrids with high-sugar type varieties were high in sucrose percentage (25 percent above US 22/3), but were low in tonnage. The F_2 populations derived from hybrids between SLC 101 and yield-type varieties produced satisfactory sucrose percentage and the yield of gross sugar per acre exceeded that of the commercial sugar beet US 22/3 (Table 2).

Different F_2 populations obtained from open-pollinated F_1 plants showed better tonnage than F_2 populations after selfing, and the average sugar percentage did not decrease with open pollination (Table 3).

Variation in Sugar Percentage in b_1 Populations

Eight of the nine b_1 triple hybrids yielded more sugar per acre than the commercial variety US 22/3 (Table 2). Some striking differences were obtained from different parental combinations. In a preliminary test the triple hybrid SL 824 x (Ovana fodder beet x SLC 101) produced the highest sugar per acre and 45 percent more than the commercial variety US 22/3. The yield of this triple hybrid was 35.4 tons per acre with 15.84 percent sucrose as compared with 29.4 tons per acre and 13.16 percent sucrose for US 22/3. The triple hybrid involving the Early Egyptian red table beet and SL 824 with SLC 101 also produced a very high yield and 33 percent more sugar per acre than US 22/3.

Segregation for Sugar Content in Different Inbred Lines

Inbred monogerm lines obtained from hybrids between different multigerm varieties and SLC 101 may be very valuable as a source for improvement of sugar percentage, since the inbred lines coming from such hybridizations have given a considerable range of sucrose percentages. Two years' results at Salt Lake City showed that inbred lines derived from hybridization of SLC 101 with multigerm varieties differing in sucrose percentage were very distinct. In most cases inbred lines, derived from crosses with SLC 101 and the high-sugar type varieties, developed higher average sugar

and percent solids than the lines derived from crosses with low-sugar type varieties (Table 4). The inbred lines derived from sugar-type parentage produced new self-fertile progenies whose refractometer readings were higher by 2 to 5 percent than those for progenies from lines derived from crosses to low-sugar type multigerm varieties. Each self-fertile F_2 beet with high sugar content is a potential high-sugar inbred line.

Discussion

Possibilities of Regulating Sugar Percentage by the Backcross Method

The backcross method (7) facilitates combining the monogerm character with resistance to different diseases such as curly top. At the same time it is possible to change the relation between sugar percentage and yield in the new varieties. The best way to do this is to utilize disease-resistant varieties which are distinct with regard to sugar type and yield type, and F_1 hybridization and for subsequent backcrosses. The results in 1950 and 1951 showed that use of curly-top-resistant varieties which differed in sugar

Table 2.—Variety Test, Granger, Utah, 1951, from Systematic Single Row Planting, with Each Row Divided into Three Lengths.

Variety or b_1 and F_2 parentage	Acre Yield: Gross sugar lbs.	Acre Yield: Percent of US 22/3	Tons beets	Percent sucrose	Percent Na
US 22/3, SL 96	7,738	100	29.4	13.16	0.112
b_1 or 1st Backcross Generation Hybrids					
SL 824 x (Red beet x SLC 101)	10,314	133	35.2	14.65	0.071
SL 824 x (Ovana x SLC 101)	11,215	145	35.4	15.84	0.061
SL 92 x (SL 92 x SLC 101)	8,026	104	31.9	12.58	0.115
SL 92 x (SL 92 x SLC 101)	8,326	108	30.5	13.65	0.115
SL 824 x (SL 92 x SLC 101)	8,474	110	29.1	14.56	0.079
SL 83-3 x (SL 92 x SLC 101)	8,256	107	31.2	13.23	0.126
SL 83-3 x (SL 92 x SLC 101)	8,776	113	30.2	14.53	0.082
US 75 x (SL 92 x SLC 101)	8,020	104	28.3	14.17	0.104
SL 824 x (US 216 x SLC 101)	7,419	96	24.5	15.14	0.080
F_2 Generation Hybrids					
Klein ZZ x SLC 101	7,132	92	21.6	15.51	0.078
SL 92 x SLC 101	8,601	111	27.8	15.47	0.091
SL 92 x SLC 101	6,448	83	20.6	15.65	0.086
Lanker x SLC 101	9,179	119	44.3	10.36	0.154
General MEAN of all varieties	8,423		30.0	14.25	0.095
S. E. of MEAN	688[2]		2.16[1]	0.55[1]	0.010[1]
Sig. Diff. (19:1)	1,947		6.21	1.01	0.028

[1] Standard errors were calculated by considering the three subdivisions of the long 420 ft. single rows as three replications. Therefore, these standard errors give only a rough estimate of the experimental error.
[2] Calculated by short-cut formula.

percentage and yield produced relatively high curly-top resistance and at the same time made it possible to change the sugar percentage and yield in the different backcross populations.

When low sugar backcross combinations of the type SL 92 x (SL 92 x SLC 101) were made the sugar percentage was about the same as that for the commercial variety US 22/3 but the yield of gross sugar was 4 to 8 percent better than US 22/3 (Table 2). Sugar percentage was increased by backcrossing the same F_1 hybrids to the sugar-type variety SL 824. These high sugar combinations did not produce high tonnage but the gross sugar

exceeded that of the commercial variety US 22/3 by 4 to 10 percent. F_1 hybrids between SLC 101 and high sugar multigerm varieties backcrossed to high sugar varieties, produced b_1 populations with good sugar but low tonnage (Table 2). The very high sugar percentage in these triple hybrids (between three high-sugar varieties) produced populations which are very valuable for breeding work when it is desired to increase sugar percentage.

A study of the backcross hybrids obtained from different combinations showed that the most valuable hybrids were obtained when varieties of different types, yield type and sugar type, were alternated in the backcrossing procedure. Diversity in parental combination for tonnage and sucrose percentage can effect increased possibilities in the breeding work that follows. Alteration of parental varieties when the backcross method is applied facilitates breeding work with monogerm beets. Such alteration of parentage increases the percentage of plants which combine desirable sugar content and tonnage in the first hybrid generations and does not diminish the grade of resistance to diseases.

High Yield Combined with High Sugar Percentage in b_1 Hybrids

Two b_1 populations, SL 824 x (red table beet x SLC 101) and SL 824 x (Ovana Fodder beet x SLC 101), produced remarkable yields. The high yields from these two triple hybrids must be due to inherent properties transmitted by the red table beet and by the Ovana fodder beet respectively. The Early Egyptian red table beet imparted a tendency for early root development, a property which is much needed in commercial sugar beet varieties. The same triple hybrid also offers opportunity for incorporation of the monogerm character with a shorter global type root. The Ovana half-sugar fodder beet, of course, imparted a very high yielding tendency. Another interesting feature of both of these triple hybrids was the low sodium percentage, 0.071 and 0.061 percent respectively, as compared with 0.112 percent from US 22/ (Table 2). The high sugar percentage from SL 824 and SLC 101 was undoubtedly responsible for this lower sodium content because of the negative correlation between sugar and sodium percentage (1).

Table 3.—Yield and Sugar Percentage in F_2 Hybrids Derived from Open-pollinated and from Selfing F_1 Plants, in June 21 Planting, 1950, at Salt Lake City, Gallinat Field.

Type of pollination in F_1	Number of populations	Average sugar percentage	Average weight per root in lbs.
Selfing	6	16.10	0.74
Open pollination	5	16.4	1.01

F_1 Male-Sterile Hybrids

Hybrids made by utilization of cytoplasmic male sterility make it possible to produce a quantity of certified F_1 or b_1 seed for commercial use. Several such F_1's were produced by use of the monogerm SLC 101 inbred line as the pollen parent. Results with these hybrids are given in another paper by Murphy, Ryser and Owen (2). These results confirm the general results obtained by the F_2 and b_1 populations shown in Table 2 with regard to the relatively high sugar percentage which the inbred SLC 101 imparts to its hybrid offspring.

Table 4.—Percent Solids in Individual Beets in Different F_2 and b_1 Populations Compared with Parental Monogerm Inbred SLC 101[1].

Parental inbred SLC 101 and Hybrid offspring	Year	Frequency distributions on percent solids																	Total beets	Ave. solids	Stand. Deviation	Coef. of variation
		15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31				
																			Number	%	%	
Monogerm SLC 101	1950					1			3	4	3	4	4	1					20	24.0	1.92	8.00
Selfed																						
F_2 (SL 92 x SLC 101)	1950			1		7	12	8	7	11	6	6	2						35	21.8	2.11	9.68
F_2 (SL 92 x SLC 101)	1951	1		3	5	8	16	9	9	9	4	0	1						65	20.7	2.08	10.10
F_2 (Klein E x SLC 101)	1951			1		4	9	7	7	3	3	1							35	21.1	1.73	8.24
F_2 (SL 941 x SLC 101)	1950							2	10	10	6	2							30	23.4	1.29	5.51
F_2 (SL 941 x SLC 101)	1951							2	1	4	6	10	7	3		1	1	2	37	25.2	2.72	9.17
F_2 (Klein ZZ x SLC 101)	1950						1		4	1	3	10	7	7	5	2			40	25.6	2.07	8.09
F_2 (Klein ZZ x SLC 101)	1951							2	8	19	25	16	20	14	2	1			107	24.6	1.69	6.84
Open pollinated																						
F_2 (SL 92 x SLC 101)	1950		1	1	3	8	22	48	50	42	29	9							213	21.9	1.61	7.35
b_1, SL 92 x (SL 92 x SLC 101)	1950				5	8	22	20	24	18	10	1							108	21.4	1.63	7.61
b_1, SL 941 x (SL 92 x SLC 101)	1950						1	3	9	13	2	1							29	22.5	2.01	4.53

[1] The percent solids were lower in 1951 than in 1950 by 4 percent. Therefore, the 1951 frequency distributions were adjusted on this basis; i.e. they were increased or shifted to the right by 4 percent.

Summary and Conclusions

Hybridization of the monogerm inbred line SLC 101 with different multigerm varieties of beets showed that SLC 101 may be described as an inbred line which improves sugar percentage in hybrid combinations. The backcross method facilitates combining the monogerm character with resistance to different diseases. At the same time it makes possible the production of hybrid populations with a desirable combination of sugar and yield for breeding work. The easiest way to obtain such populations consists in making subsequent backcrosses to varieties distinct in sugar and tonnage, which are, at the same time, resistant to the given disease.

Very promising results were shown in triple hybrid combinations. The triple hybrid which produced the highest yield of sugar per acre included parentage from the high-sugar variety US 35/2 and the Ovana half-sugar fodder beet with the inbred SLC 101.

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Influence of Geographical Locations and Type of Bag on Selfed-Seed Setting for Sugar Beets

R. K. Oldemeyer and H. L. Bush[1]

The greater use of inbreeding, in sugar beet improvement, has emphasized the problem of seed setting under bags with this plant, which is ordinarily self-sterile. Even though the sugar beet is relatively self-sterile it is possible to obtain a few seeds by self-pollination from nearly all plants under proper environmental conditions.

The Great Western Sugar Company undertook during 1950 and 1951 to determine the type of selfing bag which allows maximum selfed seed set, and to test several geographical areas to study this influence on selfed seed production in bags. This was an extensive continuation of previous investigations.

An extensive survey of types of bags in relation to selfed-seed set was made by Brewbaker. (1)[2] His studies at Fort Collins indicated that a handmade vegetable parchment bag, approximately the size of a 12-pound bag made from 30-pound parchment paper, produced the most bagged seed and the highest percentage of bags with some seed—actually 87 percent. Smaller parchment bags, factory-made of 40-pound parchment paper, resulted in the poorest seed set. Eight and 12-pound Kraft or hemp bags were slightly below handmade vegetable parchment bags in percentage of plants which produced selfed seed. In connection with this study of bags, the location effect of bagging plots was also considered and it was concluded that higher elevations were conducive to seed-set in bags. Virginia Dale (elevation 7,000 feet) appeared better than Fort Collins (elevation 5,000 feet) in this respect.

Records of bagged seed production of the Great Western Sugar Company in previous years indicate that the location of the bagging site has a profound influence upon bagged seed production. Bagging plots at Estes Park, Colorado, at an altitude of 7,200 feet, in 1937 and 1938 produced a much greater yield of bagged seed than was produced at Longmont. However, the Estes Park location proved hazardous because of the short growing season. The bagging group at Billings, Montana, in 1945 produced a much larger seed-set than Longmont; however, in 1944 and again in 1946 the bagged seed production at Longmont equalled or supassed that at Billings. A direct comparison of the Longmont and Lyons areas in regard to seed setting in bags was made in 1942. The bagging sites at Lyons lie in or at the base of the foothills, at about 5,400 feet altitude. The results showed that 20 percent more plants bore seed at Lyons than at Longmont. The percentage of plants which produced 100 or more seedballs, based on eight bags per plant, was 31 percent at Lyons and 17 percent at Longmont. These results confirmed the results of previous experiments, and the bagging operations were therefore moved to the Lyons area.

In an extensive study in 1937 by this Station, Kraft bags proved superior to parchment bags made of 25-pound and 30-pound paper. In 1949, also at this Station, 10 percent more plants produced bagged seed in Snowfibre (bleached Kraft) than in regular Kraft bags.

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[2] Numbers in parentheses refer to literature cited.

Materials and Methods

Six locations in the Colorado mountains and two in Oregon were selected as sites of bagging groups in 1950. Four locations in Colorado were studied in 1951. The location and description of the sites are summarized in Table 1.

Table 1.—Locations, Elevations, Date Planted and Date of Bagging Completion of Sites in Bagging Experiment.

Location	(Feet) Elevation	Date Planted	Date Bagging Completed
Colorado			
Lyons, 1950	5,400	April 26	June 30
1951		April 16	July 5
Salida, 1950	7,100	April 27	July 6
1951		April 27	July 8
Va. Dale, 1950	7,000	May 16	July 17
1951		May 15	July 16
Livermore, 1950	6,000	April 28	July 17
Milner, 1950	6,500	May 10	July 14
Yampa, 1950	7,900	May 17	July 14
Parshall, 1951	7,580	May 4	July 12
Oregon			
Medford, 1950[1]	1,300		June 10
Salem, 1950[1]	300		June 5

[1] Bagging was done in commercial seed plantings.

Roots from two commercial O-P varieties, GW 304 and GW 305, were planted in 1950. Inasmuch as there was no significant difference in seed yield between varieties, the results are not reported separately. GW 359 was planted in 1951 at all locations.

The brands of bags, all of the 12-pound size as used in these studies, are as follows:

1. Kraft—brown.
2. Snowfibre—white, obtained by bleaching Kraft by the sulfate treatment.
3. Golden Gate—white, semi-bleached with the sulfite treatment.

In 1950 Kraft and Snowfibre bags were compared, and in 1951 Kraft, Snowfibre and Golden Gate were compared. Each plant was bagged with one of each kind of bag. Approximately the same amount of floral branch in about the same stage of development was placed in each bag. The bagging was done just prior to the opening of the first blossoms.

The results are reported as mean number of seedballs per bag, percent of bags yielding seed and percent of bags yielding 10 or more seedballs for each type of bag and for each location.

Discussion of Results

The results of the exploratory bagging experiments are summarized in Table 2.

Location performance can best be evaluated by comparing the results obtained with Snowfibre bags at the different locations. Results using Snowfibre bags were obtained at all but one location in both years, and the results with Snowfibre bags indicate that they are the most desirable type of bag, among those studied, for use in bagging.

Results for 1950 indicate that Salida is one of the best locations tested. In 1950, Snowfibre bags yielded about twice as much seed per bag at Salida

as at Yampa, the next best location, with 182 and 101 seedballs per bag respectively. The Salida site, in 1950, also exceeded all other locaions except those in Oregon in percentage of bags producing seedballs, and in percentage of bags yielding 10 or more seedballs. The results at Medford Oregon, are based on too few bags to be conclusive. Based on the limited data a larger percentage of plants yielded seed in Oregon than at any other location. The seed production at Salida in 1951 was considerably less than in 1950; however, the percentage of Snowfibre bags yielding 10 or more seedballs per bag was higher for this location than at any other location in 1951, except Virginia Dale, where the number of bags harvested was small. The beets at the Yampa and Parshall sites were frozen down before seed could mature. The Milner site was hailed, and the bags at Virginia Dale were heavily infested with insects in 1950.

Table 2.—Results of Bagging at Nine Locations with Kraft, Snowfibre and Golden Gate 12-pound Bags.[1]

Location	No. Plants	Mean No. Seedballs/bag K	S	G	Percent bags yielding seed K	S	G	Percent bags yielding 10+ seedballs K	S	G
Lyons, 1950	98	23	50	....	60	80	....	40	61	....
Lyons, 1951	101	42	69	81	78	78	79	61	60	65
Salida, 1950	84	124	182	....	89	99	....	81	96	....
Salida, 1951	103	35	84	82	73	97	92	54	76	73
Va. Dale, 1950	103	16	28	....	39	56	....	28	40	....
Va. Dale, 1951	63[2]	74	96	118	85	88	100	76	81	85
Livermore, 1950	66	54	89	....	74	89	....	59	74	....
Milner, 1950	30[3]	11	....	....	48	....	....	30	....	....
Yampa, 1950	69	74	101	....	81	87	....	59	67	....
Parshall, 1951	102	11	38	60	45	80	82	24	56	64
Medford, Ore., 1950	26[4]	67	58	....	93	100	....	64	100	....
Salem, Ore., 1950	76[5]	45	53	....	92	97	....	52	81	....

[1] Kraft, Snowfibre and Golden Gate bags are referred to as K, S and G, respectively, in the column heading.
[2] Results based on 34 Kraft, 16 Snowfibre and 13 Golden Gate bags on different plants.
[3] 30 Kraft bags only were harvested.
[4] Results based on 14 Kraft and 12 Snowfibre bags on different plants.
[5] Results based on 40 Kraft and 36 Snowfibre bags on different plants.

Considering the present data for both years, there appears to be no great difference between the better locations *viz.* Lyons, Salida, Virginia Dale and Livermore. If mean temperature at anthesis is the main factor for setting bagged seed, the bagged seed at Salida, Virginia Dale and Livermore should be relatively high because those areas are situated at higher altitudes where the mean temperature is relatively low. The mean temperature at the Lyons locations may be rather low because of the diurnal flow of cool air down the canyon from higher altitudes and because of the shading effect of the high canyon walls. Likewise, seed setting at the Oregon locations may be influenced by the relatively low mean temperature as conditioned by the stabilizing effects of the ocean. The growing season of locations at elevations of 7,500 feet or more is unquestionably too short to mature seed on sugar beets.

White bags proved superior to Kraft bags in nearly all comparisons. Kraft bags yielded more seed per bag than white bags only at Medford, Oregon, where the number of comparisons was low and the bags were on different plants. White bags were superior as to percentage of bags which

yielded seed at all locations, and were inferior to Kraft bags only at Lyons in 1951 in regard to the percentage of bags which yielded 10 or more seedballs.

There was very little difference between the performance of the two types of white bags. Golden Gate bags were slightly superior at Virginia Dale and Parshall but had no superiority at Lyons or Salida. However, the quality of the Golden Gate bags, as used, was somewhat inferior to that of the Snowfibre inasmuch as considerably more hail damage was noted for the Golden Gate bags in the regular bagging plots.

Lower temperatures within the white bags and/or increased light transmission through the white bags are probably the determinants for white bags yielding more seedballs per bag than Kraft bags. Brewbacker (1) has reported that the mean temperature in white bags was lower than in Kraft bags. An observation made in the regular bagging plots reveals that the reason, not the determinant of greater seed production in white bags, is apparently the fact that the branches in white bags continue to grow and flower while branches in brown bags become chlorotic and cease to flower shortly after the bag is placed on the branch. It has been observed during the threshing operation that seed in Kraft bags does not occur at the terminal ends of the branches and that seed in white bags occurs more or less uniformly over all the branches.

Kraft bags are superior to white bags in regard to strength. At Milner, 1950, one-half of the Kraft bags were undamaged by hail while all the Snowfibre bags were damaged. The lack of resistance to hail was also evident at Virginia Dale in 1951 where 34 Kraft, 16 Snowfibre and 13 Golden Gate bags were undamaged after a severe hail where 110 of each bag type was present at the time it hailed.

Summary and Conclusions

The Great Western Sugar Company undertook in 1950 and 1951 to locate a geographical area under which maximum selfed-seed will be set, and to determine the type of selfing bag which would allow maximum selfed-seed set

Six locations in Colorado: Lyons, Salida, Virginia Dale, Livermore, Milner and Yampa; and two locations in Oregon: Medford and Salem, were tested in 1950. Four locations in Colorado were tested in 1951: Lyons, Salida, Virginia Dale and Parshall The range in altitude was from 5,400 feet at Lyons to 7,900 feet at Yampa. Two types of 12-pound bags, Kraft (brown) and Snowfibre (white) were tested in 1950. In 1951, Golden Gate (white) bags were also tested.

The Salida location exceeded all other locations in mean number of seedballs per bag in 1950, yielding nearly twice as many seedballs per bag as the next best location, Yampa. The Oregon locations excelled in percentage of bags yielding seed and percent of bags yielding 10 or more seedballs. In 1951, the results at Salida were less favorable than in 1950, but even so the results were somewhat more favorable than at the other locations.

White bags, Snowfibre and Golden Gate, were about equal in the production of selfed-seed and both excelled Kraft bags.

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Observations on F_2 and F_3 Generations of the Sugar Beet Hybrid, Leaf Spot Resistant Multigerm X Monogerm SLC 101

DEWEY STEWART[1]

F_1 seedlings (*Mm*) were received from Dr. V. F. Savitsky (1)[2] who had introduced the monogerm (*mm*) race of sugar beets in 1948. Roots of the leaf spot-resistant varieties U.S. 216 and N-71, occurring as the mother parent in the matings, were supplied to him from selections made under severe disease exposure at the Plant Industry Station, Beltsville, Maryland.

Observations on F_2 Generation

The *Mm* plants in the heterogeneous progenies obtained from the matings indicated above were identified by a genetic marker, *R*. In August, 1950, seeds from 64 F_1 plants were planted separately in a plot at the Plant Industry Station and the F_2 progenies were overwintered in the field. The following spring, as the stalks began to elongate, the F_2 plants were examined and those with flower buds in clusters were removed from the field before they had shed pollen. At first, some difficulty was experienced in establishing the limits of the parental phenotypes in the segregating populations since a few F_2 plants appeared to be intermediate with respect to the number of flowers in an axis. Twin flowers and double fruits had been observed, though rarely on plants of SLC 101, therefore it was thought that the occurrence of an occasional axis with twin flowers on an F_2 plant otherwise single was fortuitous or within the limits of expression of the *mm* genotype. However, if a single cluster of three flowers was found on an F_2 plant, it was classed as multigerm (*M*-) and removed from the plot. Also helpful in classifying the plants was the observation of Savitsky (1) that in monogerm sugar beets a branch and a flower do not arise in the same axis. After the final inspection, there remained in the plot 783 monogerm segregants for study.

The F_2 monogerm plants were strikingly unlike in vigor, leaf shape and type of fruiting branch. The tendency which had been observed in SLC 101 for fruiting branches to become fasciated, covered with small bracts, and more or less devoid of flowers, was frequently encountered in the F_2 progenies. The dark green, gauffered leaf characteristic of the unthrifty SLC 101 was found also in the monogerm segregants of all sizes, but not to the exclusion of the broad, rather smooth leaf type of the leaf spot-resistant parental lines. A vigorous, robust F_2 monogerm plant with an attractive foliage is shown in Figure 1.

The fruiting branches of the monogerm plants were enclosed in paper bags before anthesis and the seed set indicated unusual self-fertility. It has been pointed out by Savitsky (1) that the monogerm race of sugar beets is distinctly self-fertile, and this tendency has been transmitted strongly to the F_2 plants.

The monogerm segregants produced some striking variations from the normal. One plant was observed with peduncles 3-4 millimeters in length

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[2] Numbers in parentheses refer to literature cited.

Figure 1. A vigorous F_2 monogerm sugar beet.

and the fruits were suspended from the stems in a striking manner. In contrast to this plant, from which the "seed" would shatter with the least shaking, there were many plants with the fruits so closely grown to the stem they were not removed by ordinary threshing operations. Obviously both the easy shattering and the non-threshing types are objectionable. The majority of the F_2 monogerm plants produced fructifications in the ordinary manner, as shown in Figure 2.

There were conspicuous differences in seed size among the 783 monogerm segregants. A larger fruit than that produced by SLC 101 is greatly desired as an aid in precision drilling, which must be obtained if the full benefit of monogerm seed is to be realized. Also, a larger germ, giving rise to a more robust seedling, would be helpful. Therefore, seed size as indicated by size of fruit was considered an important selection character in the F_2 progenies and plants producing large fruits were given a high rating.

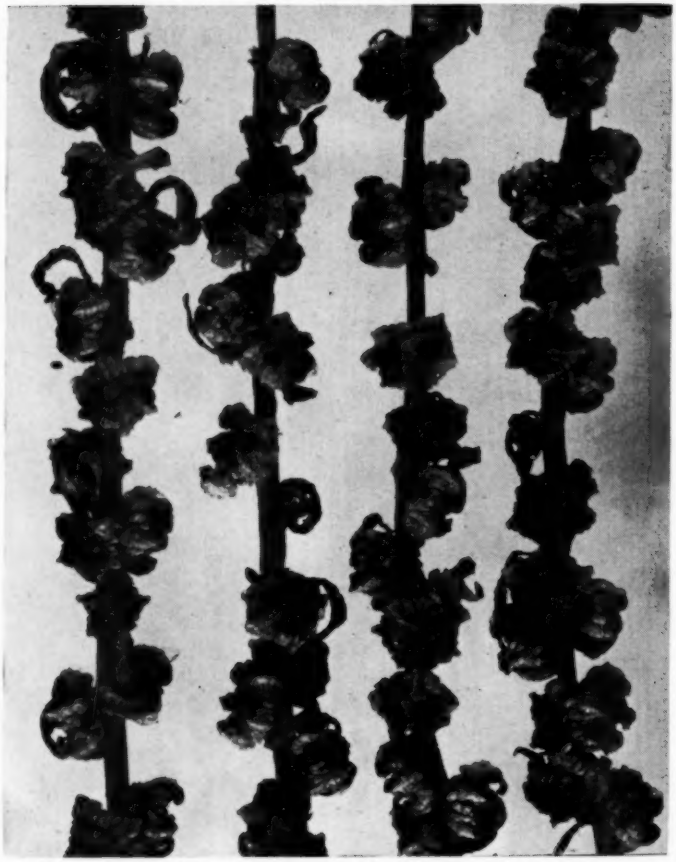

Figure 2. Fruiting branches of F_2 monogerm sugar beet showing excellent seed set.

The contrast in fruit size and size of true seed between the monogerm parent, SLC 101, and a monogerm F_2 plant (51101-460) is shown in Figure 3.

Plants were classified as to seed size by means of a set of screens with holes 6/64- to 12/64-inch in diameter. The seeds of a plant were passed through the set of screens and the portion retained on each was weighed separately. The screen size which would have retained at least 75 percent of the total was taken as the seed size of the plant. The seed size of all monogerm plants occurring in six rows, taken at random, was determined in this manner. The distribution of 200 plants in the various seed size categories is shown in Figure 4.

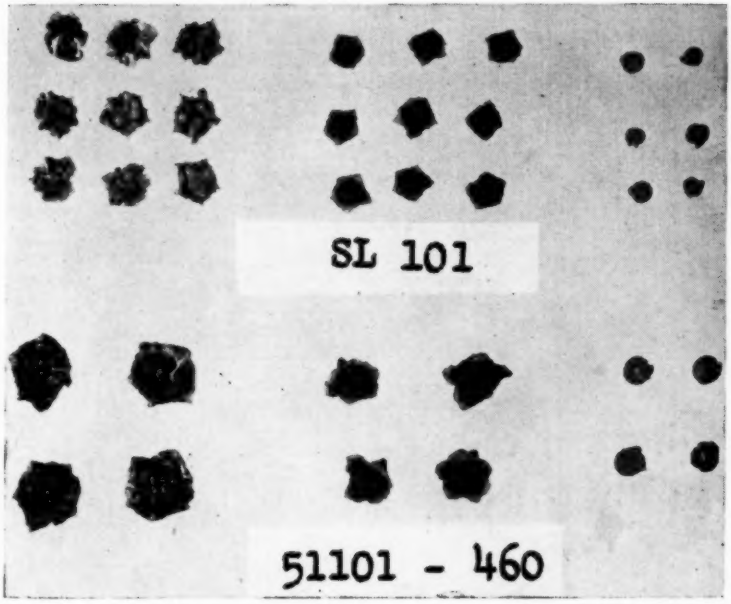

Figure 3. Comparison of fruit and seed size of SL 101, the monogerm parent, and a large-seeded F_2 plant, No. 460. The natural fruits are shown on the left. In the center, the corky material has been removed by sulphuric acid treatment. On the right, representative seed sizes are shown.

In a similar manner, the seed size of a few plants of the parental varieties grown elsewhere was determined and these have been shown in comparison with the F_2 monogerm plants. Plants of the monogerm parent SLC 101 occurred in the 7/64 and 8/64 categories, and plants of the multigerm parent U. S. 216 produced seed graded as 11/64 and 12/64. In the sample of 200 F_2 monogerm plants, 24 (12 percent) were graded as 7/64; 89 (44.5 percent) as 8/64; 70 (35 percent) as 9/64; 16 (8 percent) as 10/64, and 1 (0.5 percent) as 11/64. There was a tendency for the seed size of the F_2 plants to approach that of the monogerm parent. Only one F_2 plant, seed lot 51101-460 (Figure 3), occurred in the same size category as the multigerm parent U. S. 216. However, 8 percent of the F_2 monogerm plants occurred in the 10/64 category which is comparable in size to small-seeded commercial varieties.

Observation on F_3 Generation

Seeds of the outstanding F_2 segregants were planted in field plots to observe the F_3 progenies as to disease resistance and vigor. Although seeds from open-pollinations were planted, the progenies under observation were essentially the result of self-fertilization, as indicated by the fact that 38 percent of the *rr* F_2 plants gave no *Rr* seedlings,, and as a group they gave

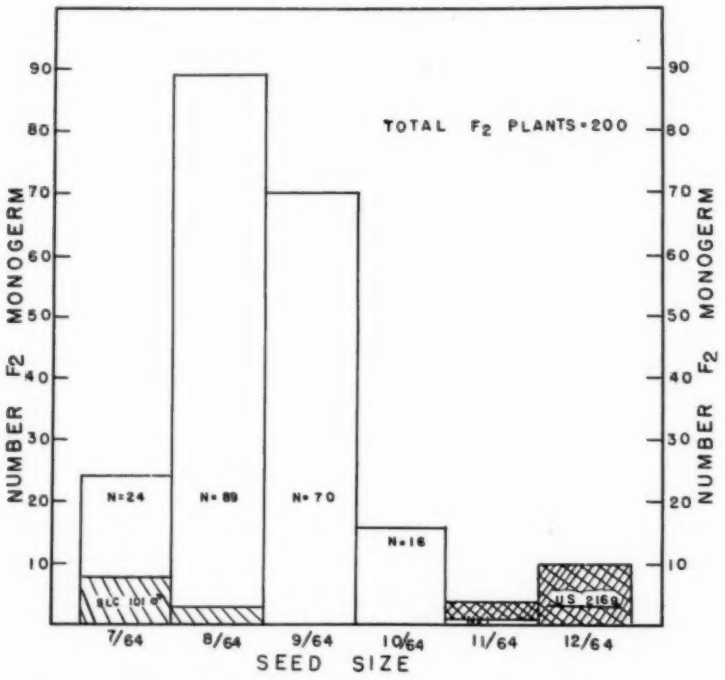

Figure 4. The distribution of F_2 monogerm segregants and the parental strains as to seed size. The seed size of a plant was taken as to the size screen which would retain 75 percent of the seed produced.

less than 2 percent. Since 50 percent of the pollen liberated in the plot should have carried the *R* gene, the absence of, or extremely low percentage of *Rr* seedlings, in the progenies of open-pollinated *rr* plants is remarkable for the sugar beet but it is in accord with the excellent set of selfed seed obtained in bags as previously mentioned.

The field plots were planted in early August and the mild autumn gave a growing season of sufficient length for the F_3 progenies to show marked difference in leaf spot reaction and vigor. The disease epidemic was not severe, but it was sufficiently intense to give a separation of the progenies of the selected F_2 plants into different categories as to disease reaction. The results are given in Table 1.

Seventy-two F_3 progenies of a total of 155 under test gave a leaf spot reading of 1, or they were placed in the same category as to disease reaction as the resistant parent, U. S. 216. If the disease exposure had been more intense and for a longer period, no doubt the 72 progenies reading 1 would have been separated further as to disease reaction. However, this

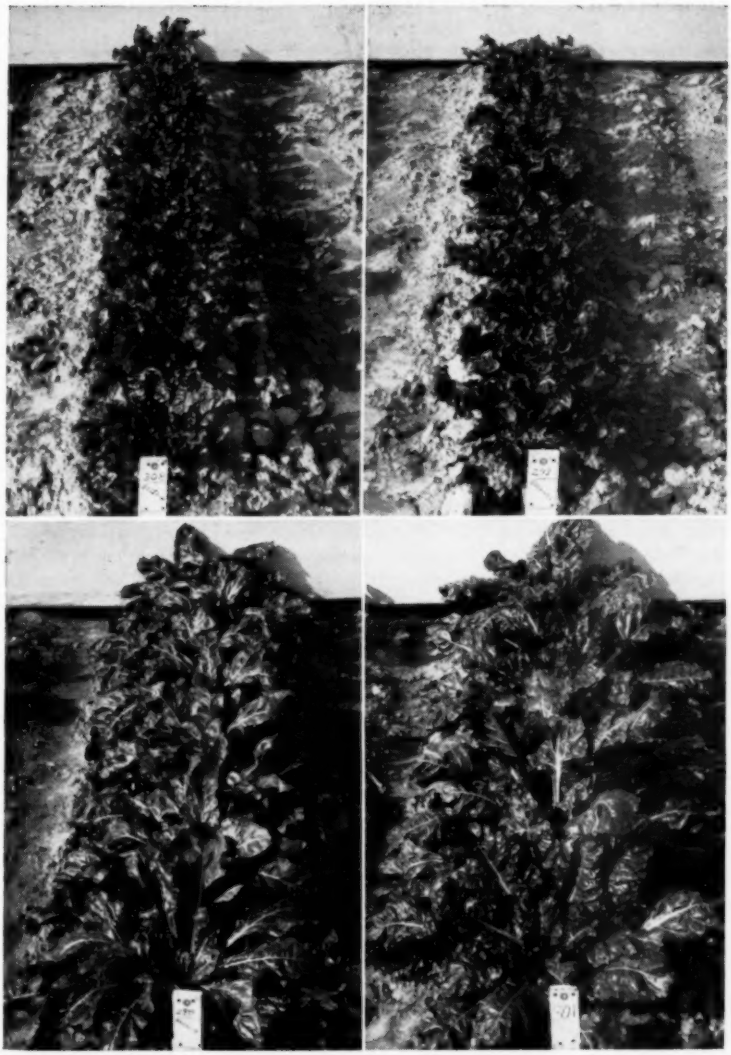

Figure 5. Upper left: SLC 101 showing gauffered leaves and unthrifty growth. Upper right: Monogerm F_3 line strikingly similar to the monogerm parent SLC 101. Lower left: Monogerm F_3 line extremely uniform for smooth open type of leaf. Lower right: Monogerm F_3 line outstanding in vigor and size of foliage bouquet.

preliminary field test served to locate the most leaf-spot-resistant lines obtained from the matings. The marked contrast in size of foliage bouquet and resistance observed in the monogerm F_3 lines is shown in Figure 5.

Although some of the F_3 lines are more leaf-spot-resistant, more vigorous and larger seeded than the monogerm parent SLC 101, it should be pointed out that they are below the level of productivity required of com-

Table 1.—The Relative Leaf Spot Resistance of F_2 Monogerm Lines and the Parental Strains, SLC 101 and U. S. 216.

Souce	Leaf Spot Reading[1]					Total
	1	2	3	4	5	
F_2 monogerm plants	72	47	22	7	6	155
SLC 101 monogerm parent	....	....	....	6	4	10
U. S. 216 multigerm parent	7	....	....	....	....	7

[1] Scale of reading: 1 = no leaf blight
5 = severe blight on older leaves
2, 3, 4 = intermediate grades

mercial varieties. There remains the problem of hybridization to bring about through the vigor of hybridity acceptable acre yields of roots and sugar. Working with economic lines strongly self-fertile presents a new experience in sugar beet breeding, but there should be no difficulty in attaining the desired goal with the introduction of cytoplasmic male sterility as a means of producing hybrid seed.

Summary

Monogerm plants were recovered in the F_2 generation of the sugar beet hybrid, leaf-spot-resistant multigerm x monogerm SLC 101. Seed size in inches was determined for 200 monogerm F_2 plants. Twelve percent were graded as 7/64, 44.5 percent as 8/64, 35 percent as 9/64, 8 percent as 10/64, and .5 percent as 11/64. The 7/64 and 8/64 inch categories were the same as the monogerm parent SLC 101. One F_2 monogerm plant produced seeds 11/64, or as large as some plants of the multigerm parent, U. S. 216. Monogerm F_3 lines as leaf-spot-resistant as U. S. 216 and far more vigorous than SLC 101 were obtained from selected F_2 plants.

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Mendelian Male Sterility in Sugar Beets

F. V. OWEN[1]

Introduction

Mendelianly inherited, or genic, male sterility in sugar beets offers different opportunities from those of cytoplasmic male sterility. Whereas the cytoplasmically inherited male sterility may be used to effect wholesale emasculation of entire populations (7)[2], and is useful for large-scale hybridization work, the Mendelian recessive gene is of more interest to the breeder in the intermediate steps of a breeding program. A point of importance is to recognize the wide occurrence of recessive genes for male sterility and to distinguish the Mendelian from the cytoplasmic type of inheritance.

To simplify terminology the recessive gene is designated *a* for abortion of pollen. From experience with other plants (3 and 9) several genes having somewhat similar effects on pollen abortion may be expected. This paper reports two different genes which are designated a_1 and a_2.

Mendelian Versus Cytoplasmic Inheritance

The anthers of the Mendelian male-sterile beets are usually smaller and more poorly developed than the anthers of the cytoplasmic male steriles. Artschwager (2) found that the microspores break down at an earlier stage in one case of Mendelian male sterility which he studied. Observations under a hand lens or low-power binocular usually make identification possible, but variations may be expected. There are particularly wide variations in case of the cytoplasm inheritance both in anther size and color and there are some variations in case of the Mendelian inheritance. Therefore, progeny tests constitute the most reliable diagnosis. When new male-sterile beets appear much can generally be learned regarding the inheritance by a progeny test from seed of individual plants harvested separately.

When Mendelian inheritance is encountered and *aa* beets are open pollinated, the offspring are all normal pollen producers, except when there are also heterozygotes in the parental population. A high-sugar selection (SL 824) from the curly-top-resistant variety U. S. 22/3 was found to be segregating for male sterility of the Mendelian type. Offspring from one open-pollinated *aa* beet produced 96 percent normal pollen producers and 4 percent male steriles, indicating a frequency of gene *a* in the parental population of about 4 percent.

In case of the cytoplasmically inherited male sterility, offspring grown from open-pollinated male-sterile beets are often 50 percent completely male sterile. A considerable percentage of semi-male steriles is also commonly observed and these constitute a relatively sure diagnosis of the cytoplasmic inheritance. Usually the percentage of normal pollen producers is relatively low but there are exceptions, depending upon the makeup of the parental populations.

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[2] Numbers in parentheses refer to literature cited.

No obvious association has been found in the inheritance of the genic or Mendelian male sterility and the cytoplasmic male sterility. Neither has any association been found between the gene a_1 for abortion of pollen and the genes tentatively designated *x* and *z* (7) which have a modifying effect on the cytoplasmic male sterility. Recessive a_1a_1 male steriles crossed to reliable type O, *Nxxzz*, pollinators (7) produced F_1 offspring all of which bore normal pollen. Selfing these heterozygous F_1 plants produced F_2 populations which gave the usual 3:1 segregation for normal pollen producers and male steriles.

With cytoplasmic inheritance for which S cytoplasm is responsible, Mendelian segregation may be observed to some extent. S *X x* beets may bear more or less normal pollen and may be self-pollinated if they also carry a gene for self-fertility. However, the writer's experience has been that these F_2 populations do not give clearcut 3:1 ratios and many intermediate or semi-male-sterile types appear. Whatever the cause of these intermediate types may be, they usually constitute a clear indication of the cytoplasmic inheritance. It may be that eventually isogenic populations can be produced in which self-pollination of S *X x* beets will produce populations with clearcut 3:1 segregation.

Table 1.—Backcross Populations, Identifying Different Sources of the Gene a_1 for Abortion of Pollen.

Population number	Classification of offspring				
	Normal	Male sterile	Total	♀	♂
4533	19	11	30	Inbred 2668	Annual 841-1
4534	10	14	24	Inbred 2668	Annual 841-1
5618	32	34	66	Annual 841-1	Inbred 2668
5619	26	21	47	Annual 841-1	Inbred 2668
5621	15	21	36	Annual 841-1	Inbred 2668
5622	24	19	43	Annual 841-1	Inbred 2668
5624	8	16	24	Annual 841-1	Inbred 2668
6850	44	49	93	Annual 841-1	Inbred 2668
6836	29	24	53	Annual 841-1	Annual 841-4
7700	21	17	38	X-rayed 3700-1	Annual 841-1
7701	29	23	52	X-rayed 3700-2	Annual 841-1
7703	31	28	59	X-rayed 3700-4	Annual 841-1
9435	9	7	16	Inbred 8T9.19	Annual 841-1
9439	9	8	17	Inbred 8T9.19	Inbred 5201
9440	6	12	18	Inbred 8T9.19	Inbred 5201
9441	15	8	23	Inbred 8T9.19	Inbred 5201
0.402	48	57	105	Inbred 5201	Annual 841-1
1.414	10	6	16	Inbred 5201	Annual 04480-4
Totals	375	385	760		
1.1 ratio	380	380	760		

The Gene a_1 From Different Sources

The recessive gene a_1 for abortion of pollen was first identified in Munerati's annual beet (1) population number 841. From this race the gene was identified in progeny from beet No. 1 in 1945 (Table 1). In 1946 the same gene was identified in progeny from beet No. 4. In 1951 the same gene was identified in a new population, 04480, of the same annual beet. The parentage of population 04480 had been carried three years

without any sign of male sterility, so it is assumed that its appearance in the offspring in 1951 represents a new mutation. Additional male steriles have appeared in other populations from this annual beet and may have been due to the same gene but progeny tests would be required for a definite answer.

Seed from Munerati's annual beet, which arose from progenies which had been X-rayed at the University of Missouri, was received in 1943 from Dr. Luther Smith. In this material 21 percent of the plants were observed to show male sterility, a much higher percentage than that observed in previous populations. The X-ray treatment may have been responsible for new mutations. Test crosses (Table 1) with beets taken from the X-rayed material indicated the presence of the same identical gene a_1 as observed in previous material.

Table 2.—F_2 Data

Population number	Classification of offspring			X^2
	Normal	Male sterile	Total	
3851	113	29	142	1.6
4535	69	10	79	6.4
4536	76	23	99	0.2
4855	18	8	26	0.8
4856	43	9	52	1.6
4858	146	52	198	0.2
4859	110	28	138	1.6
5850	51	14	65	0.4
6839	55	17	73	0.1
7709	24	8	32	0
7710	11	3	14	0.1
02.13	120	40	160	0
	5% point of probability			3.8
	1% point of probability			6.6

Observations of inbred lines showed that the appearance of occasional male-sterile beets was a common phenomenon. Progeny from male-sterile beets taken from three entirely separate lines (Table 1) gave good 1:1 ratios in hybrids to known pollinators heterozygous for a_1, which is proof that the gene a_1 was responsible for all these cases of male sterility from the widely separated sources. The 1:1 ratios shown in Table 1 would not be possible if a different gene were involved.

A Second Gene a_2

In 1948 open-pollinated seed from a single male-sterile beet was furnished by Dr. Sidney Ellerton from England. The offspring grown from this seed were all completely normal pollen producers, indicating that the inheritance was of the Mendelian type instead of the cytoplasmic type. However, test crosses made in 1950 and observed in 1951 showed that a new gene, a_2, must be involved.

Examination of Genetic Ratios

Table 1 lists 18 different backcross populations which segregated for the gene a_1. The observed results in each of these populations were com-

pared with expected 1:1 ratios by using Mather's method (6). No highly significant deviations from expected 1:1 ratios were observed.

Table 2 shows F_2 data from 12 different populations. With one exception, the observed results agree well with expected 3:1 ratios. A poor 3:1 ratio of normals to male steriles is shown for population 4535. Here the deviation from expectancy represents the 1 percent point of probability.

Linkage Tests

Previous studies (8) have shown only one well-established linkage group in beets. The gene *R* for red hypocotyl color was found to be linked with several other genes, including the gene *Tr* for trout or spotted leaves. Table 3 shows results with one backcross population which indicates no linkage between the gene *R* and the gene a_1. Three backcross populations failed to show linkage between the genes *Tr* and a_1. These results indicate that the gene a_1 is not located in the same linkage group with *R* and *Tr*.

A test for linkage between the gene a_1 for pollen abortion and the recessive gene *m* for the monogerm character (10) is shown in Table 3. In an F_2 population of 160 plants there is no evidence of linkage between these two genes.

Table 3.—Linkage Tests Between Gene a_1 for Abortion of Pollen and the Color Genes *R* and *Tr* and the Gene *m* for Monogerm Character.

Population number	Designations[1]			Classification of offspring				
	X	x	y	XY	xY	Xy	xy	Total
Backcross populations								
6850	*R*	*r*	a_1	22	22	25	24	93
6836	*Tr*	*tr*	a_1	19	10	13	11	53
7700	*Tr*	*tr*	a_1	9	12	9	8	38
7701	*Tr*	*tr*	a_1	16	13	11	12	52
			Total	66	57	58	55	236
			Expected	59	59	59	59	236
F_2 population								
02.13	*M*	*m*	a_1	85	35	32	8	160
			Expected	90	30	30	10	160

[1] Genic designations are as follows:
R = Red hypocotyl and crown color
r = recessive to *R*
Tr = Trout leaf (closely linked to *R*)
tr = recessive of *Tr*
M = multigerm
m = monogerm (independent of *R*)

Discussion

As more attention is given to developing inbred lines of sugar beets it will be more and more important to give serious consideration to the genetic principles involved and to learn as much as possible from experience with other plants, including naturally self-fertile plants. During the process of inbreeding the breeder automatically narrows the base of the germ plasm. This makes it necessary from time to time to make outcrosses to incorporate new genes. Fisher (5) has discussed the advantages of maintaining heterozygosity for a few selected genes during the process of inbreeding. This involves the production of larger populations than can conveniently be

obtained by artificial emasculation. Therefore, Mendelian male sterility should be an invaluable tool in accomplishing the desired heterozygosity in self-fertile inbred lines of beets.

The utilization of a backcross procedure in convergent improvement work in self-fertile crop plants, as advocated by Briggs (4), offers many advantages. As homozygosity is approached in successive backcrosses, the important gene or genes which are being transferred from one line to another are subjected to more careful study than they receive in any other way. The method is particularly applicable to the genetic study of disease resistance and for the practical production of disease-resistant varieties.

To facilitate future work, the gene a_1 for abortion of pollen has been retained or introduced into several curly-top-resistant inbred lines of beets, including some monogerm lines. Now, in addition to using a gene for pollen abortion, the possibility of utilizing the gene *B* for bolting or annual habit is also being investigated. With the gene *B* present, thermal induction is no longer necessary and three or four generations can be grown in a single year under warm temperatures and continuous illumination. After the desired degree of homozygosity has been reached in successive backcrosses and the desired gene or genes have been transferred from the non-recurrent parent to the recurrent parent, genes *B* for bolting and *a* for abortion of pollen may be eliminated by selfing. No injury should result to the final inbred by carrying gene *B* for bolting up to the last backcross operation. So long as the bolting or annual habit is produced by a single gene and segregation is clearcut, this should not influence the bolting tendency of the final inbred.

The gene a_1 for abortion of pollen is most useful if it can be found in the choicest inbreds without taking time to incorporate the gene. Evidence indicates that by a consistent search in populations of a few hundred plants this may often be possible. Male-sterile mutants have appeared in a wide variety of material. Whether the mutation rate is so high that the gene may be found in any inbred is a point of much interest which needs investigation.

Summary

A gene, designated a_1 for abortion of pollen, was identified in four widely different races of beets. A second gene a_2 was found in material obtained from Dr. Sidney Ellerton in England. No linkage was found between the gene a_1 and other genes tested which included the color genes *R* and *Tr* and the gene *m* for the monogerm character.

The recessive gene a_1 apparently bears no relation to previously described examples of cytoplasmic male sterility. In F_2 populations 3:1 ratios of normal to male-sterile beets were observed and in backcross populations the expected 1:1 ratios were obtained. The frequent occurrence of the gene a_1 in widely different sources of material, including one source which had been X-rayed, indicates a relatively high mutation rate.

Mendelian male sterility is useful for emasculation of individual plants in various genetic investigations and improvement programs, especially in

connection with convergent improvement of inbred lines or incorporation of desirable genes into established inbreds. To facilitate backcross operations, a suggestion is made that the gene *B*, for bolting or annual habit, may be used in connection with a gene *a* for abortion of pollen. In the final product genes *B* and *a* are both eliminated.

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Attempts to Induce Parthenogenesis in Sugar Beets[1]

JOSEPH NAMAZIE AND H. L. KOHLS[2]

Introduction

It has long been known that some plants produce seed by parthenogenesis, the development of an embryo from an unfertilized egg. The study reported here is concerned with attempted parthenogenesis by stimulating the stigma of male-sterile sugar beet flowers with different compounds, following the suggestion made by Tschermak (13)[3].

In the case of sugar beets, a desirable character may be introduced by crossing to a plant carrying this character. If parthenogenesis could then be introduced and a haploid could be obtained, some progeny would carry the new character. Changing these haploid plants to diploid by the use of colchicine would develop homozygous plants without several generations of self pollinating. Thus, seed production by pathenogenesis may be helpful in producing homozygous parent strains suitable for breeding stock.

Review of Literature

According to Sharp (12) we have two types of parthenogenesis.

1. **Reduced parthenogenesis:** In this case the developing gamete has the reduced number of chromosomes.
2. **Unreduced parthenogenesis:** In this case the developing gamete has the unreduced (zygotic) number of chromosomes.

The reduced parthenogenesis has been demonstrated in datura, tomato, wheat, tobacco, maize, pepper and many other plants. The first reduced parthenogenesis in plants was recorded by Blakeslee (1) in 1922 in datura and developed as a sport. Since then many workers have obtained haploid plants by crossing different species together (3), x-raying the young spikes (8), by heat treatment of the pollinated but unfertilized flowers (9), and from twin seedlings (4).

In recent work with corn, Chase (2) crossed a purple plumule-colored plant (pollen parent) with a colorless plumule plant (female). The progeny were all purple (the purple color is dominant) except a few that were white. Those with a colorless plumule were tested for haploidy by morphological characters and by counting the chromosomes of the root tips.

The incidence of haploidy was affected by both parents and varied from 0 in 4,500 to a high of 1 in 145 seedlings. The haploid plants could be recognized since, in comparison with diploids, they were shorter, less vigorous with more slender stalks, narrower leaves, smaller and sterile panicles and smaller glumes.

Unreduced parthenogenesis occurs frequently in vascular plants as a standard reproductive phenomenon and the resulting plant is not necessarily homoyzgous since it is like the mother plant genetically. Characrinita, Marsilea, Thalictrum are examples. Artificial parthenogenesis has been induced in Spirogyra and Chlamyd omanas (5) by growing them in six percent solution of cane sugar.

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[3] Numbers in parentheses refer to literature cited.

Recently Tschermak (13) reported the formation of seed by dusting the carefully emasculated flowers with different compounds such as road dust, dead pollen, maize powder, crushed betaxin, cebione tablets, oat meal, wheat flour, chalk, etc. He repeated the dusting until the stigma was visibly dried. He states that the seed obtained by stimulating wih different compounds are not haploid but, rather, diploid. The explanation for diploid parthenogenesis, as translated from Tschermak, is that the development of the unfertilized egg cell was stimulated by the treatment and then was changed to the diploid condition by a single skipping of cell division after nuclear division.

According to Mendel's fundamental law, in a single factor hybrid the F_1 generation has two kinds of gametes, A and a, in equal numbers which when selfed produce a ratio of 1 AA:2Aa: 1 aa. If A is dominant a phenotypic ratio of 3:1 is obtained. If the F_1 is stimulated to produce seed parthenogenetically, we would get the A and a types to develop in equal numbers, giving a ratio of 1:1 homozygous for each factor.

Overpeck, Conklin and Blakeslee (10) explain the process of seed setting and fruit ripening which normally takes place after pollination in three separate steps.

1. **The preparation of the medium in which the seed has to develop:** This consists in the prevention of abscission of the fruit and the stimulation of the development of the ovary, the ovuals with their integuments and, in some cases, the nucellus after pollination but before actual fertilization. This can be shown in Meilandrum where, after pollination, the ovary and ovules are enlarged considerably before the pollen tube has reached the embryo sac.

Pavolachko (11) reported that, if the style of Nicotiana are removed three hours after pollination, the pollen caused the development of the ovaries and delayed dropping.

2. **The stage of embryo production:** It consists of the division of the polar nucleus and the egg cell and these initial divisions are not necessarily connected with fertilization (in the sense of fusion of nuclei). Ferguson (6) observed that after pollination of petunia the polar nucleus may divide many times before the sperm nuclei have left the pollen tube. The mere presence of the pollen tube in the embryo sac seems to be sufficient to cause the initial division of the endosperm. Jorgensen (7) observed that in the cross of *Solanum nigrum* by *Solanum luteum* the sperm nucleus never fuses with the egg nucleus but the sperm nucleus degenerates. Its presence, however, is sufficient to start the division in the egg cell which ultimately develops into a completely maternal plant. (Eighty percent of such plants are diploid while the other 20 percent are haploid).

The observation of twin embryos indicates that a haploid embryo can start development under the influence of the fertilization of an adjacent ovule. This indicates that, if a diffusable substance stimulates the development of the egg, its area of activity may be limited. This might be due to either a large sized molecule which permeates membranes with difficulty or to a more readily diffusable substance with a high rate of destruction.

3. **Fusion of egg polar nuclei with sperm nuclei:** A definite step in typical seed development is the fusion of the sperm nuclei with egg and

polar nuclei which makes hybridization possible. It has been shown that the nuclear fusion is neither necessary for growth and enlargement of the ovary and ovules nor for development of the egg into an embryo. Polyembryony, common in many plants, presents the best example of embryos formed from somatic maternal tissue. This occurs, however, in the presence of an embryo resulting from fertilization. Sporophyte polyembryony among citrus shows true embryos which are developed from the nucellus. A seed of an orange regularly contains several viable embryos, only one of which may be the result of fertilization. The nonsexual seeds will produce seedlings each with a genetic constitution like that of the female parent.

Experimental Procedure

Six male-sterile sugar beets were isolated in the greenhouse in March, 1950. On a portion of a branch, the stigmas were treated with different chemicals and labels were tied at both ends of the treated sections. One of the beets was untreated. The chemicals were applied with a camel hair brush to the stigmas. The time of application was not regular but an attempt was made to treat the flowers at different stages from bud to mature flowers.

The treatments were: 1—chalk, 2—wheat flour, 3—maize extract, 4—flour, 5—soap stone, 6—maize pollen, 7—sodium nucleate, one percent, 8—sodium nucleate solution two percent, 9—sodium nucleate powder, 10—clipping the tip of the branches, and 11—control (nothing applied).

On May 15 the greenhouse temperature rose excessively and the windows were opened. This may have led to pollination of some of the flowers from sugar beet plants from a nearby section of the greenhouse. In order to better analyze the results of this experiment the seed balls produced were divided into three classes.

1. From early flowers which produced seed balls before the windows were opened.
2. From mid-early flowers which produced seed balls which may be cross-pollinated.
3. From late flowers which initiated seed balls after the day when the windows were opened.

Three of the male-sterile plants had white hypocotyl and the other three had red hypocotyl. The seeds from white hypocotyl plants were tested since they should have given all white hypocotyl progeny if the seed were produced by parthenogenesis. This germination test showed that a high percentage of the seedlings were red and indicated that the red seedlings, at least, were the result of fertilization. A count of the beets in nearby greenhouses showed 33 white and 77 red. These white plants very likely were the parents of the white seedlings. Even the seed produced early gave a high percentage of red seedlings. Apparently there was considerable contamination by outside pollen both before and after the windows were opened. Evidently a much more positive protection from pollen source must be provided for sugar beets.

Chromosome counts were made from root tips of about 15 of the white hypocotyl progeny and all were diploid, $2n = 18$. The plants appeared normal in growth habit. From this experiment, the results of which are given in Table 1, no proper conclusion can be drawn on the occurrence of parthenogenesis.

A few male-sterile annual beets were planted in the greenhouse in the summer of 1950. During the fall three plants bolted but because of the temperature most of the growth was vegetative.

One plant was treated with vitamin B_1, another with vitamin C and the third was kept as a control. The vitamins were applied by pepper shaker on alternate days until the stigma was dried. This required six applications. Eleven branches, some on each of the three plants, were bagged and no other treatment applied. No seed was formed on any of the plants, but it was observed that by application of these vitamins, in the form of powder, the ovaries were stimulated and were larger in size than untreated ovaries.

Table 1.—Number of Seeds Obtained on Each Sugar Beet Plant. Experiment 1.

Beet No.	Stage of flower	Treatment	Color of Bud	Number of seeds	Color of Hypocotyl	
					Red	White
I	Early flower	None	Red	3	1	2
	Late flower	None	Red	1	1	—
				4	2	2
II	Early flower	None	Red	12	9	3
	Mid early flower	None	Red	9	7	2
	Late flower	None	Red	55	37	18
				76	53	23
III	Early flower	None	Red	3	1	2
	Mid early flower	Sodium nucleate powder	Red	2	2	—
	Late flower	None	Red	8	3	5
				13	6	7
IV	Early flower	None	White	7	6	1
	Mid early flower	None	White	7	2	5
	Late flower	None	White	26	14	12
				40	22	18
V	Early flower	None	White	9	2	7
	Mid early flower	Sodium nucleate powder	White	2	—	2
	Mid early flower	None	White	2	1	1
	Late flower	None	White	8	3	5
				21	6	15
VI Control	Early flower	None	White	41	28	13
	Late flower	None	White	40	30	10
				81	58	23

Two male-sterile plants were isolated in a greenhouse where there was no possibility of stray pollen. The flowers were treated with different chemicals from bud stage to mature flowers and at different times of the day.

The 611 seed obtained with the different treatments shown in Table 2. when planted, did not germinate. Each seed ball appeared normal but when cut open neither embryo or endosperm was present. The hormones caused the formation of parthenocarpic fruits.

Summary

An attempt was made to induce by parthenogenesis homozygous line-

of male-sterile sugar beets by stimulating the stigma of the flowers with various compounds, following the suggestion of Tschermak.

Substances in the form of powder, vitamin compounds, chalk, etc., applied to the stigma of sugar beet flowers did stimulate the growth of the ovary but no seed was obtained.

Hormones, in the form of dust or liquid, stimulated growth of the ovary and embryo sac. The seed ball and embryo sac were normal in size and appearance but no embryo was formed.

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A New Leaf-Spot-Resistant Variety

DONALD F. PETERSON AND C. E. CORMANY[1]

Leaf spot is an important factor influencing sugar production in our producing areas in the Arkansas valley of Colorado. A variety highly resistant to this disease is necessary to insure continued production in this area. The following report details the history and performance record of our new leaf-spot-resistant variety, M.W. 131, developed for this area.

History

A planting of 35 leaf-spot-resistant breeding numbers was made at Miles City, Montana, in 1945. All of these numbers had been selected for leaf-spot resistance at various locations in previous seasons. There were at least 20 varieties involved in the pedigrees of the 35 numbers planted in 1945. A moderate leaf-spot infection occurred naturally in this planting in the late fall of 1945, and a total of 228 roots which appeared to be free, or nearly free, of leaf spot were selected and sent to Sheridan for storage and thermal induction. This group of roots produced seed in 1946 under the number of 601-00.

In tests in the Arkansas valley in 1947, 601-00 was outstanding in leaf spot resistance and showed a considerable increase in both sucrose and tonnage over U. S. 215 x 216, the commercial variety in use at that time. Accordingly, a selection of 52 roots, again free or nearly free from leaf spot, was selected and sent to Sheridan for storage and seed production. These roots produced seed under the number 8124-0 and this variety was first tested in 1949.

Performance Record

The performance data on these two varieties and the commercial check being used at that time are summarized in Table 1.

Table 1.—Production Data from the Arkansas Valley Area on Two New Varieties and Commercial Check for Years 1947-1951.

	% Sucrose	Tons/Acre	Gross Sugar	L.S.R. Index 0-10[4]
U. S. 215 x 216[2]	100	100	100	5.2[2]
601-00[2]	102	110	113	2.8[2]
8124-0[3]	101	119	121	1.9[1]

[1] One year's data.
[2] Average of five year's tests.
[3] Average of three year's tests.
[4] 0: immune; 10: susceptible.

It is readily apparent that the variety 601-00, on the basis of five years' data, is a better producer than the commercial check by about 13 percent. Also, the variety performed consistently the same in each of the five years. Leaf-spot readings were available in three years of the five and nearly identical observations were made in each of the three years. This new variety is being issued to growers in 1952 under the number M.W. 111.

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It is also clear that the newer selection, 8124-0, on the basis of three years' data, can be expected to further increase our production in this area. A total increase in sugar per acre of 21 percent is shown for the three-year period. Improvement in resistance to leaf-spot can also be noted. This new selection is being increased at the present time and will be released to our growers in 1954 as M.W. 131.

Summary

Two new leaf-spot-resistant varieties have been produced and tested in the Arkansas River valley for growers of the Holly Sugar Corporation. The first new variety, M.W. 111, shows an increased production of 13 percent over the commercial check for the five-year period, 1947-1951. The latest selection, M.W. 131, shows a 21 percent increase in production based on the three-year period, 1949-1951. Each successive selection also shows superior leaf-spot resistance.

A New Non-Bolting, Curly-Top-Resistant, Sugar Beet Variety, U. S. 75

J. S. McFarlane and Charles Price[1]

Introduction

A variety of sugar beets is needed in California which combines non-bolting with high curly-top resistance. Each of the three principal commercial varieties now in use possesses one or the other of these characteristics, but none is adapted to fall plantings in areas where curly top is severe. The non-bolting U. S. 56/2 variety most nearly meets this requirement, and is widely used for October plantings in the Imperial Valley and for winter plantings in the coastal valleys. Recent date-of-planting experiments demonstrate that sugar beets could be planted still earlier in the Imperial Valley if a variety were available with the bolting resistance of U. S. 56/2 and the curly-top resistance of U. S. 22/3. Such a variety is also needed for fall plantings in the central valley and for late fall and early winter planting in those sections of the coastal valleys subject to curly top.

This paper describes the new U. S. 75 variety which offers promise of fulfilling these needs.

Origin of U. S. 75

The U. S. 75 variety is the product of cooperative breeding research involving the U. S. Department of Agriculture, the Curly Top Resistance Breeding Committee and the Spreckels Sugar Company. In 1946, Dr. Leroy Powers, plant breeder for the Spreckels Sugar Company, made a non-bolting selection from U. S. 22/3 at Salinas, California. Seed was produced from the selected mother beets in 1947, and a portion of it was assigned the government designation, SL 731. Tests completed in the spring of 1948 showed that an improvement had been made in both bolting and downy-mildew resistance. A second mass selection was made in August, 1948, from a September, 1947, planting of SL 731 at Salinas, California. A total of 44 mother beets was selected on the basis of bolting resistance and high refractometer readings, and planted as a group in an isolation plot. Of these, 33 survived and produced seed which was assigned the number, C975. Increases of this seed were made at Medford, Oregon, and gave rise to the variety, U. S. 75.

Results with U. S. 75

Bolting

Replicated plantings of U. S. 75 and other non-bolting varieties were made in September, 1949, and 1950 at Salinas, California. The results are shown in Table 1 and Figure 1. U. S. 75 proved to be similar in bolting resistance to U. S. 56/2. It was significantly more non-bolting than U. S. 15.

Curly Top

Comparisons of the curly-top resistance of U. S. 75 with those of U. S. 22/3 and other commercial varieties were made at Jerome, Idaho, in 1950

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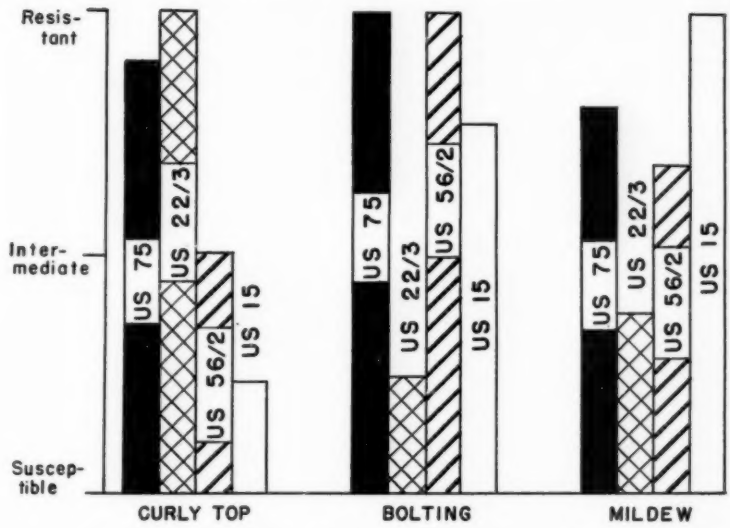

Figure 1. The relative resistance of four sugar beet varieties to curly-top, bolting and downy mildew. In making this graphic comparison, the most resistant variety has been represented as resistant, even though a higher degree of resistance may be obtained through breeding.

and 1951 by Albert M. Murphy, agronomist with the Division of Sugar Plant Investigations. The results in Table 1 and Figure 1 showed that the resistance of U. S. 75 approached that of U. S. 22/3 which is the most highly-resistant of our commercial varieties. U. S. 75 was more resistant than either U. S. 56/2 or U. S. 22/2.

Downy Mildew

Tests were made in field plots under conditions favorable for mildew during the springs of 1950 and 1951. In 1950, the environmental condi-

Table 1.—A Comparison of the Bolting, Mildew, and Curly-top Resistance of U. S. 75 with the Resistance of Commercial Varieties.

Variety	Bolting		Mildew		Curly Top[1]	
	1950	1951	1950	1951	1950	1951
	(%)	(%)	(%)	(%)	(Grade)[2]	(Grade)
U. S. 75	39	50	31	34	1.9	1.8
U. S. 15	66	78	21	36	—[3]	—
U. S. 56/2	39	59	41	49	2.8	2.5
U. S. 22/2	—	—	—	—	2.5	2.2
U. S. 22/3	—	95[4]	50	42	—	1.0
Sig. Diff. (Odds 19:1)	10	7	5	6		

[1] Curly-top data courtesy Albert Murphy, Twin Falls, Idaho.
[2] Curly-top grades range from O = No curly top to 5 = Severe curly top.
[3] U. S. 15 had a grade of 4.0 in 1949.
[4] Not replicated.

tions were especially favorable for infection at thinning time, and for about a month following thinning. In 1951, the heaviest infection occurred between emergence and thinning. Counts were made when the plants were about six weeks old, and the results are shown in Table 1 and Figure 1. U. S. 75 was significantly more resistant than either U. S. 22/3 or U. S. 56/2 in both 1950 and 1951. Inasmuch as the incidence of mildew is influenced both by the environment and by the age of plants at the time of the infection, additional tests will be required to definitely establish the relative resistance of U. S. 75.

Table 2.—Comparison of the Acre Yield and Sucrose Percentage of U. S. 75 with Those of Commercial Varieties at Salinas and Shafter, California.

	Salinas December 1949 Planting		Shafter March 1950 Planting		Shafter November 1950 Planting	
Variety	Yield	Sucrose	Yield	Sucrose	Yield	Sucrose
	(Tons)	(%)	(Tons)	(%)	(Tons)	(%)
U. S. 75	25.5	14.07	38.2	11.96	45.2	10.95
U. S. 15	23.5	14.82	.....	.....	15.6[1]	11.91
U. S. 56/2	24.7	14.38	.....	.....	45.5	11.50
U. S. 22/3	.....	.....	37.2	11.99	.....	.....
Sig. Diff. (Odds 19:1)	3.1	.94	2.9	.51	4.0	.50

[1] Severely damaged by curly top.

Yield and Sugar Content

The yielding ability of U. S. 75 was determined in a 1950 test at Salinas, California, and in 1950 and 1951 tests at Shafter, California. The results in Table 2 showed that U. S. 75 may be expected to produce a yield of gross sugar similar to that of our present commercial varieties. A tendency existed for U. S. 75 to have a slightly lower sucrose percentage than either U. S. 15 or U. S. 56/2.

Conclusions and Summary

A new, non-bolting, curly-top-resistant, sugar beet variety designated U. S. 75 is being released for stock seed production. The variety has been developed by selection from the U. S. 22/3 variety.

Tests conducted during 1950 and 1951 demonstrate that U. S. 75 is similar to U. S. 56/2 in bolting resistance, approaches U. S. 22/3 in curly-top resistance, and is superior to U. S. 22/3 in mildew resistance. Yield trials have been promising, but have not been extensive enough to warrant recommending the variety for widespread commercial planting.

U. S. 75 is recommended for extensive trials in those districts where fall plantings are made under conditions favorable for curly top.

Breeding for Resistance to Curly Top in Hybrids With Monogerm Beets

ALBERT M. MURPHY AND V. F. SAVITSKY[1]

Introduction

The original parental monogerm plants, SLC 101 and SLC 107, were derived from the curly-top-susceptible variety Michigan Hybrid 18. Therefore, it was not expected that these monogerm beets would show curly-top resistance.

Experimental Methods

To obtain monogerm curly-top-resistant varieties, the first monogerm beets (SLC 101 and SLC 107) were crossed to the multigerm curly-top-resistant self-sterile strains SL 92, SL 824, SL 88-3 and SL 941 furnished by Dr. F. V. Owen, and to the non-bolting variety U. S. 75 furnished by Dr. J. S. McFarlane. SL 92, a selection from the widely grown commercial variety U. S. 22/3, represents the very highest degree of curly-top resistance. SL 824, also known as U. S. 35/2, is a high-sugar type also selected from U. S. 22/3. SL 88-3 and SL 941 represent hybrids between U. S. 22/3 and the sugar-type variety U. S. 35. The non-bolting variety U. S. 75 was developed from two successive selections from U. S. 22/3.

F_1 seed was produced by bagging the plants of self-sterile curly-top-resistant varieties and pollinating them with pollen from monogerm beets. In order to speed up the breeding program, F_1 seed was produced in the greenhouse at Salt Lake City during the spring of 1949. Through the courtesy of Vernal Jensen, F_2 hybrids and most of the backcross populations were produced in the Amalgamated Sugar Company greenhouse at Ogden, Utah, and ripe seed was harvested in early June, 1950.

Study and selection of hybrids in 56 F_1, F_2 and backcross (b_1) populations were conducted in a special nursery during the summer of 1950 and 1951 at Jerome, Idaho. Each hybrid was planted in a single row 480 feet long. The curly-top exposure was increased by planting these hybrid populations in June and also by the procedure worked out in the beet breeding field whereby plantings were made adjacent to susceptible beets planted about two months earlier. The field in which this work was done bordered the semi-desert weed areas which harbor the beet leafhopper. Virulent strains of the curly-top virus were introduced by transplanting diseased beets from the previous year. When the seedlings emerged from the test plantings the older susceptible beets were already showing severe curly-top symptoms. These older beets also served as a host for new generations of virus-bearing beet leafhoppers. The late planting of the hybrid populations in this environment provided a very effective method for selecting for curly-top resistance. In September an appraisal of curly-top resistance was made for each population of beets and expressed as a curly-top grade recorded with a range of one to five. Selections from the plantings were made in November.

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Experimental Results

Resistance to Curly Top in Parents

During the two years of the experiment, SLC 101 showed only a low degree of resistance to curly top (Table 1). The original variety Michigan Hybrid 18, in which SLC was found, was still more susceptible and, in fact, was as susceptible as any European variety tested.

Table 1.—Curly-top Resistance of the Monogerm Beet SLC 101 Compared with F_2 Populations, Backcross Populations and Different Sugar-Beet Varieties.

Variety	Year	Average curly-top grade[1]	Percent of plants with curly-top grades,[1] as follows: 1	2	3	4	5
Monogerm SLC 101	1950	4.15	—	—	19	46	35
Monogerm SLC 101	1951	4.31	—	—	8	54	38
Mich. Hybrid 18	1950	4.84	—	—	—	17	83
Klein E., SL 1-300	1950	4.84	—	—	7	33	60
Klein E., SL 1-300	1951	4.42	—	—	8	42	50
US 33, SL 333	1950	3.97	—	—	26	49	25
US 33, SL 333	1951	3.80	—	—	36	36	24
US 35/2, SL 824	1950	2.00	16	72	8	4	—
SL 92	1950	1.86	30	56	12	2	—
SL 92	1951	1.64	50	38	10	2	—
F_2 Populations derived from SL 92 x Monogerm SLC 101							
F_2 open pollinated	1950	2.40	6	64	16	12	2
F_2 open pollinated	1951	2.34	18	40	34	6	2
F_2 self-pollinated	1951	2.30	14	26	22	24	14
Backcross populations							
SL 92 x (SL 92 x SLC 101)	1950	2.36	10	66	2	22	—
SL 92 x (SL 92 x SLC 101)	1951	2.06	24	48	22	4	2
SL 824 x (SL 92 x SLC 101)	1950	2.22	14	62	12	12	—
SL 824 x (SL 92 x SLC 101)	1951	2.16	28	40	20	8	4
SLC 101 x (SL 92 x SLC 101)	1951	3.74	—	2	20	44	34

[1]Curly-top grades: 1—plants showing very little infection
2—plants showing slight leaf curling
3—plants showing pronounced curling and some dwarfing
4—plants showing pronounced curling and dwarfing
5—plants near death from the disease

First Hybrid Generation F_1

Hybridization of the monogerm beet SLC 101 with curly-top-resistant varieties increased the resistance in the F_1 hybrids as compared with the susceptible parent. A similar increase in resistance was observed in triple hybrids derived from backcrosses of the curly-top-resistant varieties to F_1 hybrids between the two susceptible varieties, the mangel or fodder beet and SLC 101 (Table 2).

F_2 Generation

F_2 hybrids between curly-top-resistant varieties and the monogerm SLC 101 showed a higher degree of curly-top resistance than SLC 101 (Table 1). F_2 populations, as expected, were not uniform with respect to curly-top resistance when compared with F_1 hybrids. The number of plants in extreme classes was higher in F_2 populations because of segregation. Both curly-top-resistant and curly-top-susceptible plants appeared in the F_2 populations. Table 1 shows that the resistance to curly top in open-pollinated F_2 populations did not decrease as compared to that in populations obtained from selfing. In the open-pollinated populations some hundreds of F_1 plants, derived from crosses to many unrelated curly-top-resistant plants with SLC 101, were propagated together.

First Backcross Generation

Hybrids in the first backcross generation derived from recurrent crosses of F_1 hybrids to curly-top-resistant varieties showed very good resistance to curly top (Table 1). High resistance to curly top was also maintained in backcross populations when different curly-top-resistant varieties were involved in the first and second hybridization. In both cases there were very few severely injured plants. On the other hand, when SLC 101 was used as a recurrent parent in the backcross operation, only a small percentage of plants showed definite curly-top resistance.

Table 2.—Curly-top Resistance in SLC 101, SL 92 and the Backcross involving a Hybrid to Mangel or Fodder Beet.

Variety	Year	Average curly-top grade	Percent of plants with curly-top grades, as follows: 1	2	3	4	5
Monogerm SLC 101	1951	4.31	....	....	8	54	38
SL 824 x F_1 (Mangel x SLC 101)	1951	2.86	6	24	50	18	2
SL 92	1951	1.64	50	38	10	2	....

Reselections for Curly-Top Resistance

Severe infection of F_2 plants at Jerome, Idaho, made it possible to conduct very rigid selection work. A total of 1,212 of the most resistant and vigorous plants in 43 F_2 hybrid populations was selected in 1950. The best of these beets were replanted in the greenhouse at Salt Lake City. The remaining were planted in the spring in a field isolation. Only a few monogerm segregates were recovered from these F_2 populations. From 1,212 plants only 69 (5.6 percent) appeared to be monogerm. In populations grown from the same F_2 families without curly-top exposure and selection, the expected 3:1 ratios were obtained for multigerm and monogerm segregates. The deficiency in monogerm plants after selection for curly-top resistance may have been caused in a significant degree by the death of *rr* plants with white hypocotyl color and also the *Rr* heterozygotes (Table 3). To obtain authentic hybrids, curly-top-resistant *rr* plants were always used as female parents and pollinated with the pollen of the monogerm SLC 101, which is homozygous *RR* for red hypocotyl color.

Table 3.—Seedling Color in F_3 Lines.

	F_2 Genotypes Determined from F_3 Segregations RR	Rr	rr	Total
Number of lines	14	13	2	29
Percent observed	48.27	44.83	6.89	100
Percent expected	25	50	25	100

It can be assumed that, because of the severe exposure of F_2 hybrids to curly top at Jerome, Idaho, the newly selected monogerm races would manifest a high degree of curly-top resistance. One of the new monogerm lines, SLC 175, and an F_1 hybrid between this line and the curly-top-resistant variety SL 824, showed high curly-top resistance in greenhouse tests conducted by Dr. N. J. Giddings in the fall of 1951. This material, which represents a combination of curly-top resistance with the monogerm character, will facilitate further breeding work for development of monogerm varieties suitable for use in areas subjected to curly-top damage.

Performance of F_1 Hybrids Between Curly-Top-Resistant and Curly-Top-Susceptible Sugar Beets

ALBERT M. MURPHY, GEORGE K. RYSER AND F. V. OWEN[1]

Introduction

Cytoplasmically inherited male sterility has made it possible to make a wide variety of F_1 hybrids on a sufficient scale for agronomic evaluation. Previous studies have shown advantages from F_1 hybrids between curly-top-resistant varieties and selected curly-top-resistant inbred lines (1)[2].

Material and Methods

Eight different hybrids between curly-top-resistant male-sterile females and curly-top-susceptible pollinators were made in field isolations near Salt Lake City. These pollinators (see Table 1) included the monogerm beet SLC 101 (2), inbreds made by brother-sister mating from Viggo Lund from Denmark, a new high-yielding source of the German variety Klein. E. (also known in U.S.A. as R. and G. Old Type) received from the late Dr. Fredrick Schneider of the Rabbethge and Giesecke Company in 1948, the German sugar-type Klein ZZ from a 1938 reproduction by the West Coast Beet Seed Company in Oregon; leaf-spot-resistant varieties including U. S. 216 and U. S. 225 from Dewey Stewart of the U. S. Department of Agriculture, and a tetraploid from Denmark from one of Viggo Lund's inbred lines. Seed of the male-sterile females was also sent to H. E. Brewbaker of the Great Western Sugar Company who made additional hybrids to high-yielding Great Western varieties as pollinators.

In 1951 comparisons were made with standard commercial varieties at three locations: under severe curly top at Jerome, Idaho; under a moderately severe natural curly-top exposure at Twin Falls, Idaho, and under an extremely light curly-top exposure at Granger, Utah, near Salt Lake City where the disease caused no measurable reductions in yield of the susceptible varieties except in the case of rare individual plants.

The curly-top-resistant varieties used for comparison were: U. S. 33, with intermediate curly-top resistance; U. S. 22/2, with relatively high curly-top resistance; U. S. 22/3, the most highly resistant variety now in commercial use, and the male sterile hybrid SL 92H1, which possesses still higher curly-top resistance. The new source of the Klein E variety was used in the comparison at Salt Lake City, but because of lack of seed the old source of Klein E (SL 1-300), reproduced in Oregon in 1941, was used in the other two tests.

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[1] Agronomist, Agent and Senior Geneticist, respectively, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture.

[2] Numbers in parentheses refer to literature cited.

Table 1.—Performance of F_1 Hybrids between Curly-Top-Resistant and Curly-Top-Susceptible Sugar Beets Compared with Standard Varieties.

		Acre Yields				
		Severe curly-top Jerome, Ida.[1]	Moderate curly-top Twin Falls, Ida.[2]		Curly-top not a factor Granger, Utah[3]	
S.L. and G.W. numbers	Description and parentage	Tons beets	Tons beets	Gross sugar lbs.	Tons beets	Gross sugar lbs.
S.L. 1-300	Klein E. 1941 reproduction	0.6	21.7			
S.L. 09	Klein E. from Germany in 1948				35.0	9,758
S.L. 333	U. S. 33	10.3				
S.L. 222	U. S. 22/2	13.1				
S.L. 024	U. S. 35/2		23.9	7,926	28.9	8,543
S.L. 96	U. S. 22/3	15.4	27.4	8,698	29.3	8,333
S.L. 05H5	(U. S. 35 MS x CT9) x Monogerm SLC 101)		24.9	8,191	27.7	8,421
S.L. 06H5	(U. S. 35 MS x CT9) x Danish inbreds)				28.2	8,877
S.L. 09H5	(U. S. 35 MS x CT9) x Klein E, SL 09)		31.4	10,333	32.6	9,347
S.L. 010M5	(U. S. 35 MS x CT9) x Klein ZZ, SL 10		26.9	8,896	28.1	8,340
S.L. 030H5	(U. S. 35 MS x CT9) x LSR Composite				28.4	8,866
S.L. 049H5	(U. S. 35 MS x CT9) x Danish 4*n*				30.7	9,247
S.L. 09H2	MS of U. S. 22/3 x Klein E, SL 09	14.4				
S.L. 92H1	MS of CT9 x U. S. 22/3	17.2	27.8			
G.W. C-568	(U. S. 35 MS x CT9) x G.W. C-304				32.0	9,331
G.W. C-564	(U. S. 35 MS x CT9) x G.W. C-359				32.8	9,532
G.W. C-479	CT9 MS x G.W. C-304				32.4	9,380
Diff. for Sig. (19:1 odds)			2.32	804	2.38	820

[1] Data from Jerome obtained from single plots, four rows wide and 100 feet long without replication.
[2] Test at Twin Falls, Idaho, had 10 replications of randomized block with 12 varieties, but the yield from Klein E (SL 1-300) was taken from an adjacent eight-row strip.
[3] Test at Granger, Utah, was a balanced lattice design with six replications of 25 varieties.

Experimental Results

Tests at Three Locations

At Jerome, Idaho, (Table 1) under the severe curly-top exposure, where Klein E was reduced to less than 1 ton per acre, the male-sterile F_1 hybrid SL 09H2 (MS x Klein E) yielded 14.4 tons per acre, which was definitely better than the 10.3 tons per acre produced by U. S. 33 and was within one ton of the highly resistant variety, U. S. 22/3. Most of these F_1 hybrid beets showed conspicuous curly-top symptoms but made a vigorous growth in spite of the disease.

Under the moderate disease exposure at Twin Falls, Idaho, the F_1 male-sterile hybrid SL 09H5, with Klein E as pollinator, produced 31.4 tons per acre. With this very high yield these beets analyzed 16.43 percent sucrose as compared with 15.89 percent from U. S. 22/3. An eight-row strip of Klein E (SL 1-300) adjacent to the test was moderately injured by curly top and yielded 21.7 tons per acre.

In the test near Salt Lake City where curly top was not a factor most of the F_1 hybrids also produced relatively high yields (Table 1). The hybrids with the Great Western varieties were essentially equal to the Klein

E hybrid. The yield of the triploid male-sterile hybrid made with Viggo Lund's tetraploid as pollinator also was excellent.

Hybrids to the Monogerm Inbred SLC 101

In cooperation with V. F. Savitsky several male sterile hybrids were made with the monogerm inbred line SLC 101 used as the pollinator. Results from the hybrid SL 05H5 are shown in Table 1. These beets were rather short but were relatively vigorous sugar beets without any serious defects which would remind one of the small beets from the inbred pollen parent. The yield of SL 05H5 was not outstanding but the sucrose percentage was high, indicating agreement with other results which showed that the inbred SLC 101 imparts high sugar percentage to its hybrid offspring.

Another hybrid, with SLC 101 as pollinator, was designated SL 05H89. It was not included in the replicated plantings but in a single observation plot of two rows 42 feet long SL 05H89 produced a yield which corresponded to 37.1 tons per acre with 13.40 percent sucrose. This was slightly higher than the yield from U. S. 22/3 in adjoining plots with a comparable sugar percentage. Apparently better combining ability was represented in the hybrid SL 05H89 than in the hybrid SL 05H5, the difference being due to the male sterile female parent.

Conclusions

F_1 hybrids between curly-top resistant and curly-top susceptible varieties showed an intermediate degree of curly-top resistance, but sufficient for commercial use in areas which have a mild to moderate curly-top exposure.

Hybrids between a new source of Klein E from Germany and curly-top resistant male steriles produced F_1 hybrids which gave an outstanding performance. One of these F_1 hybrids produced yields slightly higher than that of the U. S. 22/2 variety under a severe curly-top exposure at Jerome, Idaho.

At Twin Falls, Idaho, under a moderate curly-top exposure, and at Salt Lake City, Utah, under a mild curly-top exposure, these F_1 hybrids had ample curly-top resistance to produce excellent yields in both tons beets and sugar per acre.

Some of the F_1 hybrids with curly-top susceptible varieties produced higher yields than were obtained by the best combinations within curly-top resistant varieties.

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Reaction of Sugar Beet Strains to Aphanomyces Cochlioides at Three Different Locations

A. R. Downie, C. W. Doxtator, J. F. Swink, D. Ogden, R. L. Bowman and J. C. Tanner[1]

The methods used in selecting sugar beets for resistance to *Aphanomyces cochlioides* (Drechs) have been adequately described (1, 2, 3)[2]. As reported, the earlier selections were all from the variety American 1, then in 1948-49 (3) additional selections were made from the American 3 and from the U. S. 33 varieties.

The purpose of this paper is to report the results obtained when the various selections are compared not only for evaluation of resistance but also to determine whether there are other sources of resistance, hence, the inclusion of genetically unrelated strains of beets which have been selected for resistance to such diseases as Rhizoctonia root rot and southern root rot.

Procedure and Results

Sixteen strains of sugar beets were grown on soils naturally infested with *aphanomyces cochlioides* at three locations in 1951. These tests were located at Mason City, Iowa; at Waseca, Minnesota, and at Moorhead, Minnesota. The Mason City and Waseca tests consisted of three replictions of two-row plots, 50 feet long, while the Moorhead test consisted of six replications with the same plot size as the other two locations.

The results for the test at Mason City are presented in Table 1.

Table 1.—Mason City Root Rot Strain Test—1951.

Variety	Description	Tons beets per Acre	% Sucrose	Lbs. Sugar per Acre
9-406-0	Elite of 1952 RR variety	8.66	12.00	2,078
9-604-0	Elite of 1952 RR variety	7.76	11.57	1,802
7-609-X	Elite of 1949-50 RR variety	7.46	11.93	1,783
0-602	RR sel. Toquam (Minn.)	7.54	11.33	1,709
0-603	RR sel. More (Minn.)	6.99	10.87	1,520
Am. 3 LSR	Com'l variety, all areas	6.52	11.97	1,559
6-423-X	Elite of 1948 RR variety	5.58	12.13	1,352
9-801	Am. 3 LSR RR sel. 1948 Moorhead	5.63	11.87	1,355
0-806	Am. 3 Drayton sel. 1949 (Minn.)	5.58	11.67	1,294
5-419	1st sel. Chaska RR 1945	5.06	11.97	1,210
1-4007	G.W. Nebr. Rhiz. sel.	5.44	10.90	1,191
0-403	So. RR sel. (Am. 5) 1 plant	4.95	11.53	1,142
0-802	M No. 23 (8-804) Best in 1949	5.88	9.73	1,136
0-404	Rhiz. sel. U. S. 22 Texas (Orig. '46)	4.46	11.73	1,039
8-804	Am. 3 N RR sel. (first)	4.63	10.90	1,011
1-9-00	USDA susc. Aphanomyces Check	3.86	12.00	927
	General Mean	6.00	11.51	1,381
	Sign. Diff. (19:1)	1.25	3.10	295

A very satisfactory epidemic of Aphanomyces root rot resulted at the Mason City location as is evidenced by the 3.86 ton yield of the susceptible check 1-9-00. That there has been steady progress in building up resistance to this disease is evidenced by the ranking of the various selections.

[1] Plant pathologist and plant breeder, respectively, at Rocky Ford, Colorado; and Research Assistants at Rocky Ford, Colorado; Mason City, Iowa; Chaska, Minnesota, and East Grand Forks, Minnesota, respectively, for the Sugar Company.

[2] Numbers in parentheses refer to literature cited.

The two highest yielding strains, 9-406-0 and 9-604-0, are the paren strains of the commercial variety to be issued to growers for the 195 growing season. The strain 7-609-X was the elite stock of the commercia variety grown in the 1949 and 1950 growing seasons. The 1948 commercia variety was a direct increase of the strain 6-423-X, which ranks seventh i this test. The first selection for Aphanomyces resistance, 5-419, which wa made in 1945 ranks tenth in yield. All of these selections were derive from the American 1 variety, and represent the progress made over th last six years.

All of the selections made from the American 3 LSR and American 3 N varieties yield about the same or less than the American 3 LSR commercial variety. Likewise, the strains of beets which were selected fo Rhizoctonia resistance, 1-4007, 0-404, and for southern root rot resistance 0-403 are also lower in yield than the commercial check variety.

The Aphanomyces root rot epidemic in the Waseca test was more severe than that experienced at Mason City. In addition, excess rainfall caused the abandonment of four of the 48 plots. In spite of this, it is felt that the results are representative. The data for the Waseca test are given in Table 2.

Table 2.—Waseca Root Rot Strain Test—1951.

Variety	Description	Tons beets per Acre	% Sucrose	Lbs. Sugar per Acre
9-406-0	Elite of 1952 RR variety	12.16[1]	10.08	2,451
7-609-X	Elite of 1949-50 RR variety	9.58	10.80	2,069
0-602	RR sel. Toquam (Minn.)	9.01	10.93	1,970
9-604-0	Elite of 1952 RR variety	8.61	10.75	1,851
0-603	RR sel. More (Minn.)	7.89	10.72	1,692
8-804	Am. 3 N RR sel. (first)	7.66[1]	9.95	1,524
0-404	Rhiz. sel. U. S. 22 Texas (Orig. '46)	7.13	11.23	1,601
0-802	M No. 23 (8-804) Best in 1949	5.68	10.00	1,136
0-403	So. RR sel. (Am. 5) 1 plant	5.52	11.10	1,225
0-806	Am. 3 Drayton sel. 1949 (Minn.)	5.06[1]	10.75	1,088
9-801	Am. 3 LSR RR sel. 1948 Moorhead	4.50	10.83	970
5-419	1st sel. Chaska RR 1945	4.49	10.77	967
1-4007	G.W. Nebr. Rhiz. sel.	4.46	10.38	926
6-423-X	Elite of 1948 RR variety	4.06	11.02	895
Am. 3 LSR	Com'l variety, all areas	3.39	10.87	737
1-9-00	USDA Susc. Aphanomyces Check	1.52[1]	10.65	324

[1] Only 2 replications.

Although not necessarily in the same order, it may be noted that the four highest yielding strains in this test are the same as in the Mason City test. These four selections, as has been pointed out, were derived from the American 1 variety.

The commercial variety ranks almost as low as does the susceptible check. This is not too unusual under very severe root rot conditions. Also, the selections from American 3 LSR and American 3 N in general are more susceptible than selections from the American 1. The beet strains selected for resistance to Rhizoctonia and southern root rot are also better than the commercial variety.

The results obtained from the test at Moorhead (Table 3) are not too different from those obtained at Mason City and at Waseca.

The Aphanomyces epidemic in this test was about the same severity as that experienced in the Mason City test. The only reason that can be given for the relatively high ranking of the 9-801 strain is that it was selected t

Moorhead and is probably better locally adapted here than at Waseca or Mason City.

Again, as was the case at Mason City, the beet strains selected for other root rots, and also the selections from 3 LSR were all about equal or poorer than the American 3 LSR commercial variety.

Table 3.—Moorhead Root Rot Strain Test—1951.

Variety	Description	Tons beets per Acre	% Sucrose	Lbs. Sugar per Acre
9-406-0	Elite of 1952 RR variety	11.41	14.08	3,214
9-604-0	Elite of 1952 RR variety	9.75	14.00	2,735
9-801	Am. 3 LSR; RR sel. 1948 Moorhead	9.91	13.71	2,706
9-602	RR sel. Toquam (Minn.)	9.46	13.68	2,584
9-603	RR sel. More (Minn.)	8.76	13.98	2,447
6-423-X	Elite of 1948 RR variety	8.58	14.02	2,391
7-609-X	Elite of 1949-1950 RR variety	8.50	13.85	2,375
Am. 3 LSR	Com'l variety, all areas	7.85	13.63	2,138
9-404	Rhiz. sel. U. S. 22, Tex. (Orig. 1946)	7.18	14.35	2,056
5-419	1st. sel. Chaska RR	7.06	14.48	2,043
9-403	So. RR sel. (Am. 5) 1 plant	6.37	14.55	1,846
9-806	Am. 3 Drayton sel. 1949 (Minn.)	6.78	13.73	1,845
9-804	Am. 3 N; RR sel. (first)	6.67	13.62	1,810
9-802	M No. 23 (8-804) Best in 1949	6.75	13.43	1,798
1-4007	G.W. Nebr. Rhiz. sel.	6.30	13.38	1,686
1-9-00	USDA Susc. Aphanomyces Check	3.62	14.29	1,028
	General Mean	7.81	13.92	2,169
	Sign. Diff. (19:1)	2.54	.56	690

Discussion and Summary

It can be stated generally that the beet strains tested at the three locations behaved quite similarly regardless of location. This was especially true of the selections for Aphanomyces resistance. It has been found over a period of the last six years that if a beet selection is resistant to Aphanomyces at Mason City it is also resistant at the two other locations.

The data obtained in these three tests indicate that definite progress is being made in building up resistance to Aphanomyces. However, additional resistance is required, as well as information as to the nature of this resistance.

The beet strains tested which were selected for resistance to Rhizoctonia and to southern root rot do not seem to have much resistance to Aphanomyces.

It must be emphasized that the severity of the epidemic usually experienced at the three testing locations is much greater than is normally found in the farmers' fields.

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Progress Report on Breeding for Storage-Rot Resistance in Sugar Beets[1]

JOHN O. GASKILL[2]

In an earlier report by the author (1)[3] strains of sugar beets, *Beta vulgaris* L., were shown to differ greatly in resistance to rotting under controlled storage conditions, and individual roots within certain strains also differed considerably in rate of rotting following artificial inoculation. A composite-inoculation technique applied to approximately 400 mother beets[4] of the wide-base, commercial, leaf-spot-resistant variety, U. S. 226, was described and illustrated. One hundred nine of the more resistant-appearing roots of U. S. 226 were transplanted in the field in the spring of 1949 and allowed to interpollinate. Approximately two-thirds of the total number survived and produced mature seed, the surviving plants varying widely in vigor and in quantity of seed produced. The seed was harvested separately from each plant. In the spring of 1950 the 20 largest seed lots were planted in replicated field plots together with two lots of the parent variety and several other varieties or strains. The plantings were made at three locations, as follows:

1. U. S. Sugar Plant Field Station, Fort Collins, Colorado: plots 2 rows x 16 ft.; 2 plots of each strain plus a systematically placed standard for visual comparisons.

2. Harry Clark farm, near Ault, Colorado: plots 2 rows x 33 ft.: 4 randomized, complete blocks.

3. J. E. Alford farm, Fort Collins: plots 2 rows x 33 ft.; 4 randomized, complete blocks.

The crop was given ordinary care in each field, with the exception of inoculation and frequent sprinkling in Field 1 for the purpose of developing an epidemic of leaf spot (*Cercospora beticola*). Leaf spot was negligible in fields 2 and 3.

Harvest results were obtained in October in Fields 2 and 3, using all roots from a carefully measured section of row (approximately 14 ft.) in each plot for weight and sucrose determinations. A representative sample of approximately 15 to 18 roots from each plot in those fields was topped, washed, stored at 65° F. for 13 weeks, and the percentage of rotted tissue determined. A duplicate set of samples was held at 45° for 20 weeks. Storage conditions and the method of rot determination used have been described previously (2). Logarithmic transformation was applied to the percentage

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[1] Report of a study made under the Research and Marketing Act of 1946. This paper has been approved for publication by the Colorado Agricultural Experiment Station as Scientific Series Article No. 378.

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[3] Numbers in parentheses refer to literature cited.

[4] Full-sized roots with crowns; suitable for growing seed.

Table 1.—Field and Storage Comparisons Between U. S. 226 and Progenies of Roots Selected from that Variety for Storage-rot Resistance.

Description	S.P.I. strain No.	Field results: Leaf spot[1] (field 1)	Fields 2 and 3[2]: Stand (hills per 100 ft. of row)	Roots per ft. of row	Sucrose	Gross sucr. per ft. of row	Storage rot[3] (field 2-65° F., field 2-45°, and field 3-65°): Log. mean	Geom. mean
		Pct.	No.	Lb.	Pct.	Lb.		Pct.
U. S. 226 (steckling increase)	471004-0	103	93	1.47	17.66	.257	2.7329	5.41
U. S. 226 (commerical increase)	Acc. 1147	94	97	1.44	18.12	.259	2.6677	4.65
Mean, U.S.226							2.7003	5.02
Progeny of 471004-0	491024-17	105	96	1.38	17.03	.234	2.2918[4]	1.96
Progeny of 471004-0	-22	96	99	1.38	18.51	.254	2.8720	7.45
Progeny of 471004-0	-26	115	96	1.52	16.95	.257	2.2643[4]	1.84
Progeny of 471004-0	-30	95	99	1.59	16.92	.267	2.7924	6.20
Progeny of 471004-0	-52	103	99	1.46	17.26	.251	2.2649[4]	1.84
Progeny of 471004-0	-56	106	99	1.37	17.65	.241	2.4547	2.85
Progeny of 471004-0	-58	108	101	1.59	17.40	.277	2.5538	3.58
Progeny of 471004-0	-61	98	91	1.39	18.25	.252	2.8060	6.40
Progeny of 471004-0	-68	78	100	1.37	17.78	.241	2.6135	4.11
Progeny of 471004-0	-70	90	98	1.33	17.63	.232	2.5843	3.84
Progeny of 471004-0	-71	55	95	1.56	17.10	.265	2.4688	2.94
Progeny of 471004-0	-75	40	94	1.57	17.41	.270	2.6676	4.65
Progeny of 471004-0	-83	89	97	1.37	17.60	.240	2.5641	3.67
Progeny of 471004-0	-86	83	101	1.41	17.66	.248	2.2217[4]	1.67
Progeny of 471004-0	-89	96	97	1.49	17.41	.257	2.5761	3.77
Progeny of 471004-0	-92	93	98	1.65	16.77	.279	2.5377	3.45
Progeny of 471004-0	-96	108	95	1.31	18.25	.237	2.4543	2.85
Progeny of 471004-0	-100	123	89	1.53	17.56	.266	2.3921[4]	2.47
Progeny of 471004-0	-104	115	96	1.39	17.99	.250	2.3926[4]	2.47
U. S. 225 (storage-rot susceptible inbred)	Acc. 1148	142	98	1.42	17.55	.248	3.2733	18.76
R. & G. Old Type (commercial check)	Acc. 1139	197	100	1.51	18.21	.275	2.9454	8.82
L.S.D. (5 percent point):								
For comparing individual strains							.3449	
For comparing any one strain with the mean for U. S. 226							.3008	

[1] Leaf-spot readings (two-plot averages) expressed as percent of standard; low percentage indicates high resistance.
[2] Each strain occurred in four plots in each of the two fields.
[3] Storage: 65° F., 13 weeks; 45° F., 20 weeks; rotted tissue in each sample determined as percentage, by weight.
[4] Mean for the indicated progeny is significantly below the mean for the parent variety, U. S. 226.

rot data for summarization and variance analyses in accordance with accepted practice (3). The plots in Field 1 were used for leaf-spot readings, no harvest or storage samples being taken. One of the progenies of U. S. 226 was dropped from the experiment before storage because of undesirable agronomic characters.

Results

The highlights of the storage results for Field 2 may be summarized as follows: 1. The overall average percentage of rot for the 19 progenies of U. S. 226 was significantly lower than the average for the parent variety; and

2. four progenies, individually, were significantly below U. S. 226, none being significantly higher. Pooling of results in this way was based on non-significant interaction of strains x temperatures and non-significant difference between the two lots of U. S. 226.

The general level of rot for each temperature, among samples taken from Field 3, was much lower than that obtained for the corresponding temperature for Field 2. This occurrence was attributed to various factors which are considered irrelevant insofar as this study is concerned. The average percentage of rot for the Field 3 roots stored at 45° F. was less than one-half of one percent, and differences between individual progenies and between parent variety and progenies were negligible. These results, representing negligible disease exposure, were disregarded. Rot among the Field 3 roots stored at 65° was higher, and the average tended to substantiate the results obtained for Field 2.

A general summary of results obtained for the 19 progenies and the parent variety is given in Table 1, together with results for a susceptible inbred and a European commercial variety which are of particular interest because of the fact that they were included in the earlier report on breeding for storage-rot resistance (1) discussed at the beginning of this paper. Since the two lots of U. S. 226 did not differ significantly in percentage of rot, the average for that variety is used as a basis for evaluating the storage-rot resistance of the progenies. Sixteen of the 19 progenies were below the parent average in percentage of rot, that is, they kept better, and, as shown in the column of logarithmic means, six of them had significantly less rotted tissue than the parent variety. None were significantly higher in amount of rotted tissue. These results confirm an earlier tentative conclusion that storage-rot resistance of sugar beets can be improved through breeding (1) and indicate one applicable method of screening mother beets for resistance. It is worthy of note that the data in Table 1 do not reveal consistent association between improved storage-rot resistance and low sucrose, low root yield, or leaf-spot susceptibility.

Summary

Nineteen progenies resulting from open pollination among sugar-beet roots which had been selected for storage-rot resistance in the spring of 1949 by means of a composite-inoculation technique were grown in replicated plots in two fields in 1950 and subsequently tested for storage-rot resistance in comparison with the parent variety, U. S. 226. Samples of topped roots from the field plots were stored under controlled conditions at 65° and 45° F. for 13 weeks and 20 weeks, respectively, and the percentage of rotted tissue in each sample then was determined on a weight basis. The amount of rot which developed in samples taken from one of the fields and stored at 45° was extremely low, and differences between strains were negligible. Consequently, those results were disregarded. In a general summary of all other storage data, 16 of the 19 progenies were below the parent variety in average percentage of rotted tissue, six of them being significantly lower. None was significantly higher. These results confirm an earlier tentative conclusion that storage-rot resistance of sugar beets can be improved through breeding.

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Preliminary Studies Applicable to Selection for Low Respiration and Resistance to Storage Rots of Sugar Beets

R. T. Nelson and R. K. Oldemeyer[1]

The loss of sucrose during storage is largely the result of respiration by the beet and/or rot caused by micro-organisms. These losses become particularly apparent in areas where piling and storage of beets is a common practice. This problem is such that it presents a challenge to all which might aid in reducing the losses. Certainly the plant breeder is not outside the sphere of responsibility in this matter should differences in storage quality exist between sugar beet varieties, or between individual beets of these varieties. Methods adaptable to individual root analysis for both respiration and rot and some results of variations in measurements obtained are presented in this paper.

Methods and Results on Respiration

Respiration rates were compared from measurements of carbon dioxide produced by a given amount of sliced tissue over a given period at a given temperature.

Sample preparation—The procedure employs 15 grams of sliced tissue from the tail of the beet. Slicing is done with a rotary vegetable slicer set to give slices 1/12 inch thick. A section from the tail of the beet having a diameter of approximately 1½ inch is used regardless of the over-all size

Table 1.—Respiration Rates at 20° C. on Sliced Tissues of Five Beets of Two Varieties Tested in Duplicate—Values are Calculated to mg. CO_2 Per kg. Tissue Per Hour.

Variety	Beet No.	Sample 1	Sample 2	Variety	Beet No.	Sample 1	Sample 2
GW305	1	159	168	GW381	1	282	295
GW305	2	172	183	GW381	2	264	259
GW305	3	191	177	GW381	3	266	266
GW305	4	196	196	GW381	4	261	253
GW305	5	248	200	GW381	5	248	240
GW305	Mean	189		GW381	Mean	263	

of the beet. Reasonably comparable transverse discs are thus obtained from each beet, though emphasis is based on weight of tissue rather than on number, size or shape of discs. After weighing, a sharpened nail is forced through the discs constituting the sample and the discs are separated so that all cut surfaces are exposed to the air. The tip of the nail holding the sample is then inserted into the underside of a No. 12 one-hole rubber stopper fitted with a capillary tube.

Measurement of CO_2—The No. 12 stopper and sample are inserted in a 200 cc. wide-mouth specimen bottle immediately after the addition of a known amount of alkali. Upon insertion, the stopper seals the bottle and suspends the tissues in an entirely closed chamber except for an oxygen

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inlet provided by the capillary tube. Oxygen is supplied from an oxygen-filled balloon through a manifold made of T-tubes connected in series, one T-tube being required for each bottle. For absorption of the carbon dioxide, 25 cc. of approximately 0.2 normal barium hydroxide has been used per sample. Blanks, including 25 cc. alkali but no sample, were included at intervals. For back-titration 0.2 normal sulfuric acid was used. For 15 grams' tissue and 19 hours' incubation at room temperature these solutions were convenient. Continuous shaking was maintained during incubation by means of a mechanical shaker making 90 ½-inch oscillations per minute. Phenolphthalein was used as indicator for titration. Taking the difference in titration value between a sample and its appropriate blank, the amount of carbon dioxide produced by respiration was calculated for this report. For selection purposes, the acid titration values were used without further calculation so long as the blank titration values remained constant.

Results—During the winter season, 1950-51, 116 respiration analyses were run per day on individual beets. This number could be increased if necessary. While it is too early to make a complete report, the results obtained to date should be of interest. Good differential results between beets have been obtained so that selection was not difficult. Reported in Table 1 is a sample of the preliminary work which was made to test method.

Table 2.—Respiration Rates at 25° C. on Sliced Tissue from Ten Individual Beets of Six Open-pollinated Varieties in mg. CO_2 Per kg. Per Hour and Analysis of Variance Table.

	Beet Number										
Variety	1	2	3	4	5	6	7	8	9	10	Mean
C455	284	229	243	279	311	241	392	325	302	369	397.5
GW305	323	311	353	291	321	272	329	336	266	346	314.8
GW304	293	275	242	329	302	302	391	352	327	362	317.5
C359	305	284	254	311	256	199	332	286	336	249	281.2
C478	359	334	291	396	350	320	403	314	284	314	336.5
GW381	284	256	351	275	307	332	282	401	291	406	318.5

Source of Variation	D.F.	Mean square	S.E.	F	F req. for sign 5%	F req. for sign 1%
Between varieties	5	3,667		1.8	2.4	3.4
Error	54	1,994	45 (C.V. = 14)			

Shown in Table 1 are some of the differences obtained between duplicate samples of the same beet, between beets of the same variety and between varieties. Variety GW381 was outstandingly higher in respiration rate when compared with Variety GW305. This is an interesting point, however: It was found in subsequent studies that the mean respiration rate of five or even 10 beets of an open-pollinated variety does not represent the population mean. That variation does exist between certain varieties was suggested from results obtained by another method previously reported (3)[2].

In Tables 2 and 3 respiration rates and analysis of variance tables are

[2] Numbers in parentheses refer to literature cited.

given for ten beets of six open-pollinated varieties and six inbred lines, respectively.

Tables 2 and 3 bring out some items of interest with regard to respiration rates. If it is assumed that inbreds listed in Table 3 are stable with regard to all characters (which may be a false assumption) the variations in respiration rates obtained within an inbred must be attributed to environment as it affects condition of roots and other factors which combine to make the error. Based on the foregoing assumption and the statistical analysis given, the only justification for selection would be between inbred lines. A guide to effectiveness of selection in open-pollinated varieties will have to await testing of progeny.

Table 3.—Respiration Rates at 25° C. on Sliced Tissue from Ten Individual Beets of Six Inbred Lines in mg. CO_2 Per kg Per Hour and Analysis of Variance Table.

	Beet Number										
Inbred	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Mean**
1,035	355	345	313	525	402	459	441	371	371	310	389.2
1,060	255	335	302	345	289	310	332	370	389	334	326.1
1,036	264	361	276	306	277	268	290	259	261	311	277.3
1,061	233	311	318	250	293	268	272	261	311	264	278.1
1,063	318	251	326	272	350	224	366	329	350	245	303.1
1,051	291	293	358	334	355	297	311	336	321	300	319.6

Source of Variation	D.F.	Mean square	S.E.	F	F req. for sign 5%	1%
Between inbreds	5	17,145		9.7	2.4	3.4
Error	54	1,763	42 (C.V. = 13)			

Method, Results and Discussion of Testing Individual Roots for Storage Rot Resistance

Method—The method of testing individual roots for storage rot resistance is an adaptation of the method developed by Gaskill (2). The method makes possible the testing for storage rot resistance in conjunction with assembly line testing for other characters.

After the beet is rasped, a 20-30° sector of tissue is sawed out just adjacent to the rasped sector. This is accomplished by passing the beet, in a rasping cup, over a circular saw. The sector is lifted out and a two-inch piece (Figure 1) is saved from the shoulder of the beet. A small tab bearing the beet number is pinned to the slice for identification.

In tests conducted in 1950-51, two areas on the epidermis of the sector, one-fourth inch in diameter, were pared off with a vegetable peeler just prior to inoculation. This method did not give 100 percent infection at the point of inoculation. Consequently, in 1951-52 the apex of the sector was sliced off and discarded and the inoculum applied to the freshly cut surface of the sector saved.

The inoculum was prepared from a pure culture of a proven pathogenic strain of *Phoma betae*. Cultures grown in three Petri plates were mixed wtih 125 cc. of water agar and diluted with an equal volume of water

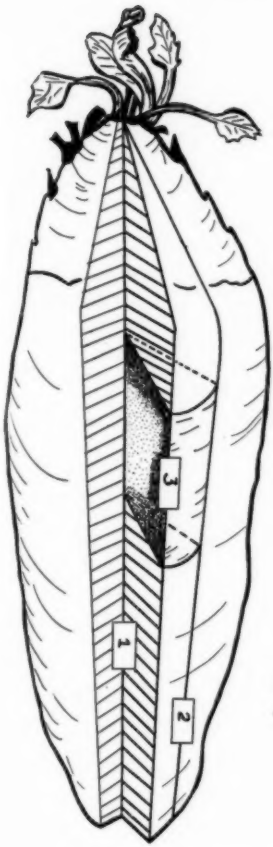

Figure 1.—Sketch of beet showing (1) rasped sector, (2) saw cut and (3) portion of root which is removed for inoculation.

to provide inoculum of ideal consistency for dropping. A drop of inoculum was placed on each pared area in 1950-51 and toward each end of the newly exposed area in 1951-52. A 24- x 30-inch tray with a one-quarter inch mesh screen bottom was used to hold the sectors. Each tray held approximately 200 inoculated pieces. An insulated waterproof cabinet with a capacity of 45 trays was built for incubating the inoculated beet sectors. Heat was controlled by a thermoregulator and supplied by three 100-watt incandescent light bulbs. A saturated humidity was maintained through the use of a medicinal atomizer attached to an air compressor and a supply of water.

The inoculated pieces were incubated for four weeks at 45° F. in 1950-51, and for 11 days at 55° F. in 1951-52. After the period of incubation, the inoculated sectors were split longitudinally through the two spots on which the inoculum was applied. The depth of penetration of the rot from the

surface was measured in millimeters at the point of inoculation. This measurement became the criterion on which susceptibility or resistance was established.

Results and Discussion—An attempt was made in 1950-51 to improve a commercial variety in storage rot resistance, among other characters, by mass selection. Pieces of 2,000 roots grown at McCook, Nebraska, were inoculated. After four weeks' incubation few pieces showed any signs of storage rot. For this reason a positive selection could not be made. Beet slices from inbred lines grown at Longmont, Colorado, however, rotted sufficiently so that between line differentiation could be made. The within line variation, as to rot penetration, was somewhat erratic.

The penetration of rots in 1951-52 obtained by inoculating the inner tissue of the beet appeared to be much more consistent than the depth of penetration obtained in 1950-51. Unmistakable differences between inbred lines are shown in Table 4.

Table 4.—The Distribution of Roots Per Class as to Depth of Penetration in Sectors of Roots of Inbred Lines and an Open-pollinated Variety Inoculated with *Phoma Betae* and Incubated at 55° F. for 11 Days, 1951-52.

Plot No.	Rot Penetration (mm)										Mean Rot Penetration mm	Mean Sugar Percent
	0-1	1½/ 2	2½/ 3	3½/ 4	5	6	7	8	9	10		
2.221	10										1.1	14.0
2.223	1	3	5	1							2.6	12.9
2.235[1]	1	3		1							2.1	13.9
2.248				2		2	1	2	1	1	7.8	10.2
2.252[1]	1	1	2	1							2.4	13.1
2.253	10										0.6	13.8
2.271A[2]	4	3	2	1							1.7	15.8
2.272A[3]	2	5	2	1							2.0	14.3

[1] Open-pollinated variety.
[2] Inbred line grown in different part of field from plots 2.221-2.253.
[3] Open-pollinated variety grown adjacent to inbred line in plot 2.571A.

The differences are also very vividly illustrated in Figure 2.

Inbred lines included on the table may be considered genetically stable as they have resulted from selfing four or more generations.

The results obtained leave no doubt that inbred lines grown under environmental conditions which favor rotting can be differentiated as to degree of resistance by this method.

Another question arises, however: Is the measure of resistance obtained by this method anything more than a measure of sugar content? A rather close relationship between high sugar content and storage rot resistance was observed and is illustrated in Table 4. Inbred lines in Plots 2,221 through 2,253 were grown with a relative lack of competition which resulted in a lowered percentage of sugar. The inbred line in Plot 2,248 which had an extremely low percentage of sugar was susceptible to storage rot and lines in plots 2,221 and 2,253, which had a relatively high percentage of sugar, were resistant to storage rot.

Figure 2.—Root slices of inbred lines after inoculation with *Phoma betae* and incubation for 11 days at 55° F. Left to right—Plot 2,221 resistant, Plot 2,223 moderately resistant and Plot 2,248 very susceptible.

Storage rot tests made on beets from the same field but under normal competitive conditions, which resulted in high percentage of sugar, failed to reveal the consistency of rot penetration which was obtained in the low sugar portion of the field. Considering the variation in readings between beets within Plots 2,517A and Plots 2,572A, the comparisons should probably be confined to between lines and made only with a large number of roots per line.

Additional information is unquestionably needed before any testing method can be said to give definite results in improvement of storage rot resistance, *per se*. Suggested lines of research would include the determination of (a) statistical correlation coefficients of sugar on storage rot resistance, (b) optimum incubation time, (c) the correct organism or group of organisms to use, and (d) optimum temperature for incubation.

Some pertinent research has been done by Russian workers (1) (4) in which *Botrytis cinerea* was used for inoculation. The incubation was conducted at 77° Fahrenheit for five or six days. Stock beets which were low in percentage of sugar were reported as most susceptible. On the other hand, Gaskill (2) reports that red garden beets which are low in percentage of sugar were the most resistant of the varieties of beets which he tested.

Summary

Methods for comparing respiration rates and storage rot resistance of individual beet roots are described. The methods are rapid and are sufficiently accurate to make what appear valid selections between inbred lines on which means have been drawn from determinations of several beets of the line. Selection on basis of individual root analysis of open-pollinated varieties remain of doubtful merit until proven or disproven by tests of progeny.

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ACKNOWLEDGMENT—Acknowledgment is due Mr. John Gaskill, Pathologist, Division of Sugar Plant Investigations, U. S. Department of Agriculture, Fort Collins, Colorado, for his helpful suggestions during the course of these investigations, and for the pure cultures of the rotting organisms which he so generously supplied.

Selection for Cold Tolerance and Low Temperature Germination in Sugar Beets

R. R. Wood[1]

Introduction

The development of varieties of sugar beets capable of germination from seed at low temperatures, together with the ability to withstand frost after establishment of the plant in spring and resistance to early freezing damage in fall, now appears to be entirely possible. The apparent advantages of such types in temperate climaxes is fairly obvious, but perhaps will bear repetition: (a) lengthening of the effective growing season in both spring and fall, (b) prevention of replanting or loss of fields due to frost damage in seedling stage, (c) indications of association of cold resistance with greater sucrose content (1)[2]. This latter advantage is probably not too obvious from superficial examination of the problem but if the preliminary evidence is supported by later investigations, the value of such selection is greatly enhanced.

Low Temperature Germination

It was mentioned in a previous publication (1) that preliminary investigations indicated wide variations between sugar beet varieties in ability to germinate from seed at low temperatures. The differences obtained were highly significant statistically and have been substantiated by subsequent investigations. Table 1 gives germination percentages obtained in a later trial and also some information as to whether or not that portion of the

Table 1.—Low Temperature Germination of 16 Varieties of Sugar Beet Seed, 1949.

Acc. No.	Germination at Low Temp.[1]	Residual[1] [2] Germination	Total Germination	Original Germination
	(percent)	(percent)	(percent)	(percent)
C453	62.1	22.8	84.9	89.0
C359	62.0	27.3	89.3	81.0
C304	60.8	33.3	94.1	91.5
C381	53.1	30.0	83.1	83.0
C305	50.3	29.3	79.6	67.5
C389	49.7	35.8	85.5	86.5
C452	38.8	47.7	86.5	74.0
C455	32.2	48.5	80.7	75.0
A84	29.7	44.0	73.7	79.3
GW201-48A	29.2	45.7	74.9	97.0
A105	26.2	40.7	66.9	70.0
A101	24.5	51.0	75.5	85.0
A100	23.8	43.8	67.6	74.5
B212	21.3	54.2	75.5	67.0
A53-42	15.8	50.8	66.6	78.0
B379	14.5	55.8	70.3	76.0

[1] Averages of six replications.
[2] Placed in germinator at normal germination temperature after those seeds which germinated at low temperature were removed.

viable seedballs which fails to germinate at low temperatures is damaged by the exposure. Blotter germinations were used throughout the present study.

It is readily apparent from Table 1 that destruction of viable germs by cold and moisture at low temperatures did not take place; actually, in

[1] Agronomist, Agricultural Experiment Station, the Great Western Sugar Company, Longmont, Colorado.
[2] Numbers in parentheses refer to literature cited.

the case of variety C452 the combined germination figures might indicate an appreciable percentage of hard seed coats made water-permeable by prolonged exposure to 34° to 36° F. temperature, plus moisture.

Selections, on the basis of germination at low temperature, were made from two commercial types, C304 and C359, extreme care being exercised to destroy locules which did not germinate before planting the sprouted seeds to pots. A comparison of progeny and parents is given in Table 2.

Table 2.—Low Temperature Germination—Progeny Test.

Acc. No.	Description	Germ. Percent[1]
C304	Parent	35.8
B585	Sel. from C304 on basis low temp. germ.	55.1
C359	Parent	29.9
B586	Sel. from C359 on basis low temp. germ.	69.0
LSD 5% point		11.9
LSD 1% point		17.1

[1] As percent of potential.

In each case selection pressure resulted in a marked increase in low temperature germinating ability in the progeny as compared with parent.

A study of low temperature germination of varieties selected on the basis of cold resistance as seedlings failed to show any conclusive evidence that the characters of germination at low temperatures and frost resistance are associated in any way. Further investigation will be required to illuminate this question. Table 3 gives data bearing on the observation above.

Table 3.—Germination of Sugar Beet Seed at Low Temperatures, 1952. 42-day Period at 34°-36° F.

Acc. No.	Desription	Germination percent of potential
C304	Parent	35.8
B573	Cold resistant selection from C304	11.6
B621	Cold resistant selection from C304	31.1
B474	Selection from C304, basis sodium content	17.1
B613	Cold resistant selection from B474	71.9
C359	Parent	29.9
B587	Cold resistant selection from C359	44.0
C455	Parent. (Beta maritima hybrid)	9.0
B588	Cold resistant selection from C455	23.4
A1104	Parent (Sugar x Garden hybrid)	55.7
B612	Cold resistant selection from A1104	47.4
A53-42	U. S. 22 (Curly top resistant)	1.3
Gr. 5123	Inbred (Leaf spot resistant)	42.8
Gr. 5124	Inbred from Beta maritima hybrid	5.5
LSD 5% pt.		17.3

Cold Resistance of Sugar Beet Seedlings

Data and photographs have been presented previously (1) demonstrating that large differences exist between varieties with respect to resistance to frost injury.

The location and extent of germ plasm carrying such frost resistance characters has been investigated. Eighty differing strains, inbred lines and varieties, representing as many different sources as were available at the Agricultural Experiment Station of the Great Western Sugar Company a

Longmont, Colorado, were tested and indexed for low temperature reaction in seedling stage. Percent survival and hardened plants after exposure to —6° to —8° Centigrade for 2.5 hours ranged from zero to 96. The relation of resistance to ecological source was not clearly defined; however, North Sea types in general appeared somewhat better in survival.

Selections in seedling stage on basis of frost resistance were made and seed produced. Progeny testing is underway at the present time and only preliminary data are available.

Table 4.—Comparison of Parent and Progeny in Cold Resistance Selections of Seedlings.

Acc. No.	Description	Percent Survival	Number Plants tested
C304	Parent, Com'l. G.W.	17.8	477
B573	Easy bolting plants from C304 selection for cold resistance[1]	27.3	452
B621	Normal bolting plants from C304 selection for cold resistance.	34.7	300

[1] Bolted as result of cold exposure when frozen.

The differences shown in Table 4 only approach statistical significance at the five percent level. Considerable difficulty has been encountered in getting uniformity of growth of the seedlings in greenhouse flats; however, later plantings have shown improvement and it is felt more precise and conclusive tests will be completed soon.

Cold Resistance in Fall Period

Previous observations (1) have indicated that large differences may exist between varieties in their reaction to cold in the fall season. Further observations were made possible in the fall of 1951 as result of a temperature of 15 degrees below zero Fahrenheit on the night of November 2, while approximately one-half the commercial beet crop was still unharvested in some northern Colorado areas. The recovery of individual beets compared with destruction of others, after such a shock, gave a very striking comparison indeed.

Sugar Loss Following Freezing

As result of the low temperature (—15° F.) mentioned in the last paragraph above, some indication was obtained as to what happens to sugar content following such exposure. This information is given graphically in Figure 1.

From this figure it appears that a decline was taking place in sugar content before the freeze occurred; actually, this is accounted for by the dates of sampling, as the last sampling prior to the freeze was accomplished two or three days ahead of that time. The dotted line would seem to give a good projection of actual conditions. Growth of the beet was apparently not affected to any great degree since weight increase was almost over for the season; this is indicated by a fairly flat tonnage curve.

The greatest interest then is centered around what happens to the sugar already manufactured and stored in the root. It is, of course, very well known that defoliation with the resulting production of new leaves uses up sugar for the growing of new parts, with the result that actual sugar content of the root is diminished; further, respiration, due to enzymatic action and rot organisms, after harvest gives a measureable sugar loss; probably there are other normal losses, but none which would seem to account for a sharp

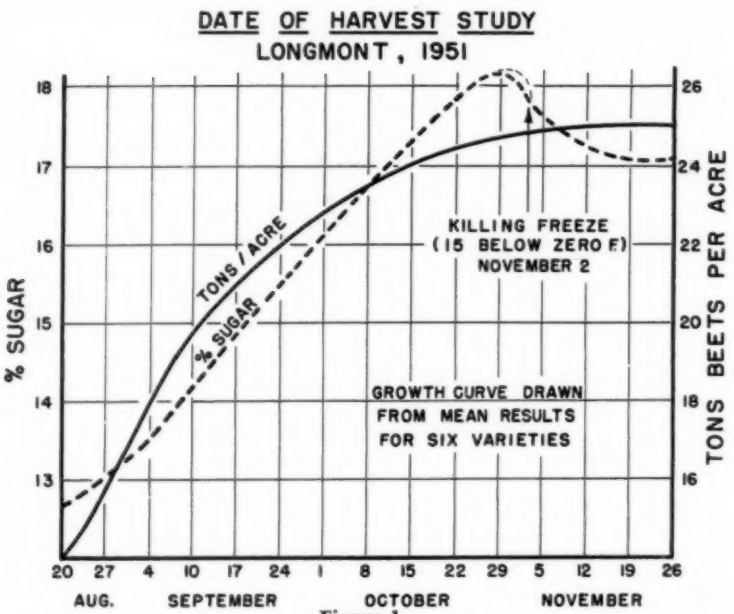

Figure 1.

drop of the magnitude demonstrated here. It should also be emphasized that in this instance production of new foliar tissue could not have been a factor in lowering sugar content.

These observations on sugar loss following frost are very well in agreement with those of Peto (2), who studied factory records at the Raymond, Alberta mill. It seems quite evident then that some other mechanism not presently explained must be involved to account for the drastic loss in sugar in beets following severe frost.

Summary and Conclusions

1. Data are presented to show that ability of beet seed to germinate at low temperatures is probably heritable and improvment should be accomplished by selection pressure.

2. Preliminary data indicate resistance of beet seedlings is also heritable in nature and can be improved by breeding.

3. Some mechanism or mechanisms appear to be involved in sugar losses, in beets in the field following severe frost, other than those at present accepted and evaluated.

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Heritable Differences in Germination of Sugar-Beet Seed at Low Temperatures

C. H. Smith[1]

In early spring plantings of sugar beets combinations of several factors are often encountered which hamper seedling emergence. One of the most common of these disturbing factors is low temperature. If soil temperatures are low, seedling emergence is slowed down very noticeably and general plant vigor is often affected, making workable stands difficult to obtain. Differences in seedling emergence between different varieties have been frequently observed in the field.

Varieties

A large number of sugar beet varieties were tested in the laboratory at both low and high temperatures. The results of only four of these are reported in this paper for illustrative purposes. SL 92 and SL 824 were selected to represent commercial self-sterile varieties, while the inbreds 867-1 and 9046A represent self-fertile curly-top-resistant inbred lines. All four of these varieties germinated more than 85 percent at 75° F. (See Figure 1) and all showed good seedling vigor at this temperature.

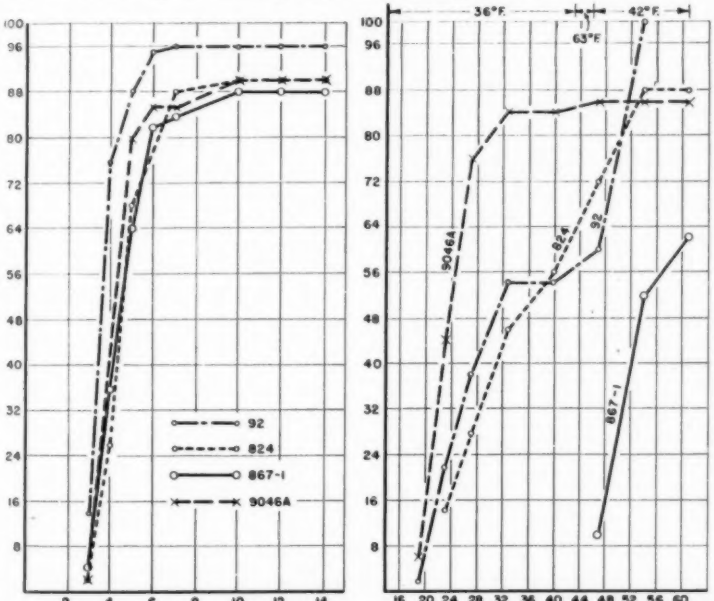

Figure 1.—Two curly-top-resistant varieties, SL 92 and SL 824, compared with two inbreds, 867-1 and 9046A. Left, germination rates at 75° F; right, germination rates at 36° F. for 44 days, 63° F. for two days followed by 42° F. for 15 days.

[1] Agronomist, Division of Sugar Plant Investigations, Soils and Agricultural Engineering, Bureau of Plant Industry, Agricultural Research Administration, U. S. Department of Agriculture.

[2] Numbers in parentheses refer to literature cited.

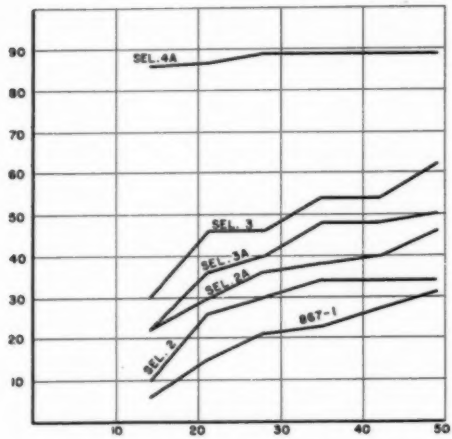

Figure 2. — Slow-germinating inbred 867-1 germinated at 43° F. and compared with reselections. Reselections 2 and 3 were reproduced by self-pollination whereas 2A, 3A and 4A were reproduced under open pollination. Reselection 4A differed greatly in vigor as well as in germination rate and is regarded as a probable outcross.

SL 92 is a curly-top selection from the widely grown commercial variety U. S. 22/3. It is a vigorous variety and germinates relatively fast even at low temperatures. SL 824, also known as U. S. 35/2, is a high-sugar variety selected from U. S. 22/3.

The inbreds 867-1 and 9046A were selected because they represent extreme differences. The germination of the inbred 9046A was remarkably fast at low temperatures as compared with other varieties, whereas 867-1 was extremely slow. Both of these inbreds were homozygous *rr* for white hypocotyl color (1)[2]. The inbred 867-1 is a highly non-bolting line, whereas 9046A is a moderately fast bolter.

Methods

Two temperatures, 75° F. for the high level and 36° F. for the low level, were used for most of the work although tests were conducted with other intermediate temperatures with the same varieties. In the low-temperature comparison illustrated in Figure 1, a temperature of 36° F. was maintained for 44 days, which then rose to 63° F. for two days and was then lowered to 42° F. for the remaining 15 days. The change in temperature during the test was not intentional as the refrigerating unit failed and the temperature of 63° F. was reached before the containers could be removed to a root storage cellar where the temperature was maintained at 42° F.

Blotters were used in the germination tests at high temperatures. At low temperatures a two-inch layer of soil was placed in containers and moistened to a desirable moisture content. The seeds were pressed into the soil surface and covered over with a one-inch layer of sphagnum moss to maintain moisture. In other tests at low temperature, 9-inch square metal pans 1½ inches deep were filled to a depth of one inch with coarse quartz sand and vermiculite (50:50 mixture by volume) and moistened to a desirable moisture content. The seed was dropped into shallow depressions in the sand surface. Metal covers were placed on each pan to prevent the

escape of moisture and to afford a suitable means of stacking. In the high-temperature tests at 75° F. daily counts were made while weekly counts were made in the low-temperature tests.

Experimental Results

At 75° F. the differences among the four varieties were rather small, but under the low temperatures the spreads between the varieties became very striking (Figure 1). The inbred 9046A gave outstanding results by its rapid germination at low temperature, whereas the inbred 867-1 was extremely slow at low temperature (Figure 1). The inbred 867-1 in other tests failed to show any germination at 36° F. for 50 to 60 days. The differences in vigor of seedlings between the two inbreds was also very striking in the low-temperature test. The inbred 9046A had exceptionally good vigor, whereas 867-1 had extremely poor vigor. SL 824 was nearly equal to SL 92 in germination rate at both low and high temperatures, but the seedling vigor at low temperature was much inferior to that of SL 92.

Selection for Increased Germination Rate

From the low-temperature test shown in Figure 1, the earliest seedlings to appear from the two self-fertile inbred lines were saved for seed production. Stecklings were transplanted to the field in early spring. Paper bags were placed over the inflorescences to obtain self-pollinated seed. However, both bagged and open-pollinated seed was saved separately and tested. Previous experience showed that these self-fertile inbreds are largely self-pollinated even under open pollination. Some individual plants showed an increase in germination rate over the parent in low-temperature tests.

Selection number 4A from the inbred 867-1 (Figure 2) produced seed with rapid germinating qualities far out of range as compared with the other reselections and the parental line. A high number of plants (66 percent) with the red hypocotyl color in this reselection indicated that it probably arose as an outcross in the previous generation. All other re-

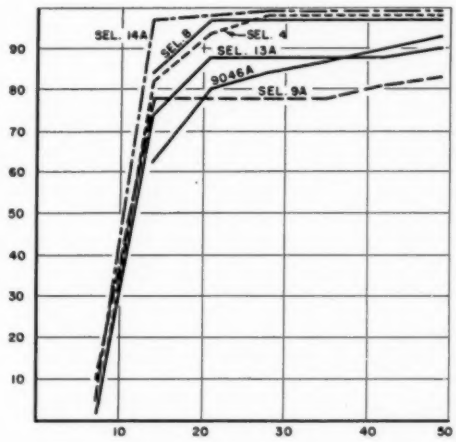

Figure 3. — Fast-germinating inbred 9046A germinated at 43° F. and compared with reselections 4 and 8 were reproduced under self-pollination whereas 9A, 13A and 14A were reproduced under open pollination.

selections from 867-1 were homozygous *rr* like the parental inbred. The general vigor of the seedlings of reselection 4A was also far superior to other selections. A similar outcross appeared in the inbred 9046A shown in Figure 3, selection 8, but here vigor of the reselection did not exceed that of the parent.

Discussion

Both rate of germination and vigor of seedlings were affected under low temperature. These characteristics seem to be heritable in certain varieties as they appear both in parental lines and reselections. Worthwhile attempts could be made for improvement of varieties by reselection work. Various methods of germinating the seed at low temperatures could be employed and seedling diseases could be considered at the same time. The "rag doll" method of wrapping up a bulk of seed, as employed by Ivanoff (2) in testing the resistance of oats to Victoria blight, is reasonably simple yet convenient for large quantities of seed.

It is believed that low-temperature tests could be run on all varieties of beets to gain a knowledge of their reactions under early spring field conditions. Through such knowledge one may better anticipate the percentage of emergence under prevailing conditions. Dr. L. Rasmusson described to the writer a procedure used in Sweden and William Gahan described a somewhat similar procedure used in Ireland. The Swedish method involves the use of a two-inch layer of crushed brick or the equivalent as a covering of the seed to simulate field conditions.

Other important factors which help determine good seedling emergence are moisture content, oxygen in the soil atmosphere, soil salts, seedling diseases, texture of the seedbed, etc. Undoubtedly all these factors play important roles in seedling emergence and differential response may be expected from different varieties. Laboratory tests may tell whether a variety is affected by one of these factors and whether improvement can be expected through reselection work.

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Breeding for Resistance to Downy Mildew In Sugar Beets

J. S. McFarlane[1]

Introduction

Downy mildew caused by the fungus, *Peronospora schactii* Fuckel, is an important disease of sugar beets in the coastal districts of California. Its seriousness has been demonstrated by Leach (3)[2], who found that infected beets produced 30 to 40 percent less sugar than healthy beets growing in the same field. Losses are particularly severe in seasons characterized by long periods of cool, foggy weather. This may be attributed to the low temperaure and high humidity requirements of the causal organism for germination and infection.

When a severe infection occurs in the seedling stage, young plants may be killed by the disease, thereby causing poor stands. Infection which occurs after thinning ordinarily does not kill the plants, but may cause permanent stunting. Leach (3) has shown that the younger a plant is when infected with mildew the more serious the damage. Losses from mildew are expressed as a reduction in size, in sucrose percentage and in purity of the beet.

The U. S. 15 variety (1) is the most resistant of the commercial varieties, and will withstand moderate attacks of the disease. The U. S. 56 variety (6) has also been shown to be moderately resistant. Leach (3) demonstrated that the mildew resistance of a variety could be improved by selection in the greenhouse, and developed an improved strain of the U. S. 33 variety.

This paper reports progress in breeding sugar beets which are highly resistant to mildew. Emphasis has been placed on the inbreeding method.

Procedure

Selections for resistance to downy mildew were made in the greenhouse at Salinas, California, during the period 1948-1951, using a technique similar to that described by Leach (3). Plantings were made in flats of steam-sterilized soil which were then placed in a warm greenhouse (20° to 24° C.) until the plants had two to four true leaves and were large enough for inoculation.

Following emergence of the seedlings, the flats were uniformly thinned to 150-200 seedlings per flat. Inoculations were made with a spore suspension prepared by washing conidia from young, recently infected beet leaves. The spore suspension was sprayed uniformly over the seedlings, using a pressure sprayer. Following inoculation, the flats were placed in a humid inoculating chamber which was maintained at a temperature of 5° to 10° C. A fresh spore suspension was sprayed over the seedlings at the end of 24 hours. The flats were removed from the chamber 48 hours after the first inoculation, and were placed in a cool, humid section of the greenhouse for disease development.

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[1] Geneticist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture.

[2] Numbers in parentheses refer to literature cited.

As mildew developed, the flats were returned to the inoculating chamber for 48-hour periods at 10-day to two-week intervals. This was continued until 90 percent or more of the plants were infected. Mildew-free plants were transplanted to the field for seed production. When selections were made in easy bolting seed stocks before February 1, it was possible to obtain a seed crop the year the selection was made. Selections made in non-bolting seed stocks and in easy bolting stocks after February 1 were carried over until the following year for seed production.

The progenies of the greenhouse mildew selections were tested for field resistance under conditions favorable for mildew development. In order to obtain a uniformly heavy infection throughout the test plots, two-row strips of a susceptible variety were planted at 20-foot intervals during the fall months. Uniform infection in these strips was obtained by transplanting mildew-infected plants at 15- to 20-foot intervals in the rows. The test plantings were made between the mildewed strips in March at a time when temperature and humidity were expected to be most favorable for infection.

Table 1.—Comparative Downy Mildew Resistance of Varieties and Selections Planted at Salinas, California, March 10, and Counted May 29, 1950.

Strain No.	Description	Percent Mildew
SL 824	Sugar selection U. S. 22/3	50.5
C 973	Greenhouse mildew selection U. S. 22/3	36.2
SL 831	Non-bolting selection U. S. 22/3	41.8
C 975	Non-bolting selection SL 831	31.2
SL 858	Curly-top selection U. S. 56/2	40.0
C 972	Greenhouse mildew selection SL 858	34.5
SL 859	U. S. 56/2	41.4
C 970	Non-bolting selection U. S. 56/2	60.6
SL 715	U. S. 15 (damaged by curly top)	20.8
Difference required for significance (19:1 odds)		5.2

The test material was planted on low beds 20 inches apart in two-row plots, 40 feet long. The beets were thinned to approximately four inches between plants. In order to reduce bias in favor of healthy plants at thinning time, the laborers were provided with 4-inch thinning guides and instructed to thin uniformly without regard to the appearance of the plants. To encourage a heavy infection, the relative humidity was increased by lightly irrigating the plantings every two or three days. Mildew counts were made in May and June.

Results

Field Tests with Varieties and Selections

In 1950, two greenhouse mildew selections and a group of commercial varieties and non-bolting selections from commercial varieties were tested for mildew resistance in a field planting using eight replications. The conditions were favorable for mildew infection at thinning time and for about a month following thinning. As is shown in Table 1, infection ranged from 20.8 to 60.6 percent. The U. S. 15 variety proved to be the most resistant, although the amount of infection may have been influenced by the curly-top disease which damaged this variety. A sugar selection from

U. S. 22/3, designated SL 824, was the most susceptible of the commercial varieties. This selection had previously been shown to be similar in mildew resistance to U. S. 22/3. The greenhouse mildew selection C973 from U. S. 22/3 showed a highly significant superiority in mildew resistance as compared with SL 824. The mildew selection, C972, was significantly more resistant than the parent stock, U. S. 56/3. The non-bolting selections from U. S. 22/3 showed progressively increased improvement in mildew resistance even though they had not been selected for mildew resistance. The most susceptible strain was C970, a non-bolting selection from U. S. 56/2.

A similar group of varieties and selections was tested in 1951 in a field planting consisting of ten replications. A severe infection of mildew occurred while the plants were in the seedling stage, but disease development and further infection were checked by high temperatures shortly after thinning. As is shown in Table 2, the range in infection was less than in 1950.

The U. S. 15 variety was among the more resistant varieties or selections, and the non-bolting selection from U. S. 56/2 was the most susceptible. The two greenhouse mildew selections, C071 and C073, tended to show a lower

Table 2.—Comparative Downy Mildew Resistance of Varieties and Selections Planted at Salinas, California, March 12, 1951, and Counted May 29, 1951.

Strain No.	Description	Mildew	
		Total	Severe
		%	%
SL 824	Sugar selection U. S. 22/3	44.8	9.5
C 071	Greenhouse mildew selection SL 824	42.3	7.7
SL 831	Non-bolting selection U. S. 22/3	42.4	10.7
C 075	Non-bolting selection SL 831	33.6	5.2
SL 859	U. S. 56/2	48.6	13.6
C 073	Greenhouse mildew selection U. S. 56/2	44.6	11.8
C 070	Non-bolting selection U. S. 56/2	63.8	27.0
C 065	Non-bolting selection F_2 (U. S. 56/2 x U. S. 22/3)	33.1	7.7
C 715	U. S. 15	36.0	7.6
Difference required for significance (19:1 odds)		6.4	3.2

incidence of mildew than the parent stocks, but the differences were not significant. The U. S. 56/2 variety proved to be one of the most susceptible of the commercial varieties, and was more severely damaged than in either the 1950 test or in tests reported by Price, Owen, and Carsner (6).

The non-bolting selection, C075, which was a direct seed increase of C975 used in the 1950 test, again showed a low incidence of mildew. A new non-bolting selection from the F_2 of a cross between U. S. 56/2 and U. S. 22/3 showed only 33.1 percent mildew, which was the lowest of any selection or variety in the test.

Field Tests with Inbreds

A preliminary test of inbred lines was made in a non-replicated field planting in 1950. Infection was heavy and occurred uniformly throughout the planting. Included was a group of inbred sublines which originated from mildew-resistant plants selected in the greenhouse from an S_2 popu-

lation of a cross between the mildew-susceptible SL 453 and the moderately resistant SL 4201.

The results with eight of these sublines and with the SL 4201 and CT9 inbreds are shown in Table 3. All eight of the sublines were more resistant than the moderately resistant female parent, SL 4201. Infection of individual sublines ranged between 2 and 24 percent, thereby making it possible to select highly resistant inbreds for increase and further study. The curly-top-resistant inbred, CT9, proved to be highly susceptible.

In 1951, a group of seven inbreds was tested in a field plot using six replications. Environmental conditions were favorable for infection from the time the seedlings emerged until the beets were thinned. A heavy incidence of mildew occurred on the cotyledons of both the susceptible and resistant inbreds. Many seedlings, particularly in the suceptible inbreds, were killed before true leaves were formed. Mildew counts were made when the plants were six weeks old and the average percent infection occurring in each of the inbreds is shown in Table 4. Infection ranged from 3.4 percent in the P2-20 inbred to 85.0 percent in CT9. Two strains of the non-bolting NB1 inbred showed good resistance, but were inferior to the three inbreds selected for mildew resistance in the greenhouse. The P2-16 and P2-20 inbreds were increases of the two sublines carrying similar numbers in the 1950 test. The original monogerm inbred discovered by Savitsky (7) proved to be intermediate in resistance.

Table 3.—Comparative Downy Mildew Resistance of Inbreds Planted at Salinas, California, March 23, and Counted May 31, 1950.

Strain No.	Description	No. of Plants	Percent Mildew
P2-2	S_2 (SL 453 x SL 4201)	121	10
P2-4	S_3 (SL 453 x SL 4201)	93	3
P2-6	S_3 (SL 453 x SL 4201)	132	14
P2-8	S_2 (SL 453 x SL 4201)	82	24
P2-10	S_3 (SL 453 x SL 4201)	140	6
P2-16	S_3 (SL 453 x SL 4201)	148	3
P2-18	S_3 (SL 453 x SL 4201)	123	15
P2-20	S_3 (SL 453 x SL 4201)	99	2
C 8255	SL 4201 selfed	262	31
SL 69	CT9, Curly-top-resistant inbred	106	92

Infection in the resistant inbreds was limited primarily to localized areas on the leaves. Rarely were plants observed which showed systemic infection of the entire crown. Later in the season, when environmental conditions became unfavorable for mildew, the plants with the localized infection could not be distinguished from non-infected plants.

Discussion

Advantages of the Greenhouse Method

Increased field resistance to mildew can be obtained by selecting in the seedling stage under controlled greenhouse conditions. This method offers some definite advantages over a field selection method, the most

important being dependability. Although environmental conditions favorable for field mildew epidemics may be expected in the spring months along the California coast, the date of their occurrence varies from year to year.

In order to be reasonably sure of obtaining a satisfactory field test, it is necessary to make two or more plantings at progressive dates. Even when this precaution is taken, a heavy infection does not always occur, and a portion of the selected plants merely escape infection. When the greenhouse method is used, temperature and humidity can be controlled, thereby insuring more dependable exposures than are possible in the field.

During a single season, one can test as many plants in a greenhouse with 500 to 1,000 square feet of floor space as can be tested in an acre field plot. This method has the added advantage of utilizing help at a time when the field program is least pressing. Selecting for resistance in the greenhouse is also less costly than in the field.

Table 4.—Comparative Downy Mildew Resistance of Inbreds Planted at Salinas, California, March 23, and Counted June 14, 1951.

Strain No.	Description	Mildew	
		Total	Severe
		%	%
P2-20	S_4 (SL 453 x SL 4201)	3.4	0.1
P2-16	S_4 (SL 453 x SL 4201)	5.7	0.9
P3-9	S_3 (U. S. 22/3 x SL 4900-14)	6.1	0.3
C 0502	NB1, Non-bolting inbred	18.3	0.6
C 0504	NB1, Non-bolting inbred	22.3	1.7
SL 101	Monogerm inbred	41.7	1.3
SL 9092	CT9, Curly-top-resistant inbred	85.0	12.6
Difference required for significance (19:1 odds)		7.3	2.5

Advantages of Selecting in Self-fertile Lines

The results of these studies have demonstrated that mildew resistance can be gained more rapidly by selecting in self-fertile lines rather than in cross-pollinated varieties or selections. Even though a group of plants is able to withstand severe exposure to mildew during the selection process, the progenies of the individual plants differ greatly in their resistance.

Unless the selected plants can be selfed and the progenies tested individually, it is difficult to separate the inherently resistant genotypes from those with only moderate resistance. Selections from cross-pollinated varieties cannot ordinarily be selfed, so it is necessary either to make massed seed increases from the group of selected plants or adopt a system of controlled crossing. If the mass increase method is used, the gain in mildew resistance from any given group of plants can be expected to be materially less than when the individual plants are selfed or crossed in pairs.

Although the cultivated sugar beet is normally self-sterile, self-fertile breeding stocks can be readily developed by incorporating the S^f gene described by Owen (4). Through the utilization of cytoplasmic male sterility (Owen, 5), mildew-resistant inbreds can be used in developing hybrid varieties of sugar beets.

Influence of Age of Plants on Resistance

The resistance of any given variety or selection is influenced by the age of the plants and by the growing conditions at the time infection occurs. Mildew is primarily a disease of young, actively growing tissue. Plants which are old and stunted can rarely be infected either in the greenhouse or field. All strains observed in these tests are most susceptible in the cotyledon stage, although strains may vary in their susceptibility at this stage of growth. As true leaves are formed, the difference in resistance between strains become more pronounced.

Summary

The progenies of selections made in the greenhouse under conditions of uniformly heavy mildew infection showed improvements in mildew resistance when tested in the field. The greenhouse method of selection proved more dependable and cheaper than the field method.

The greatest gains in resistance were made by selecting in self-fertile lines rather than in cross-pollinated varieties and selections. The variability in mildew infection among inbred lines ranged from 3 to 85 percent, and demonstrated the heterozygosity of the cultivated sugar beet for mildew resistance. The possibility of developing highly resistant hybrid varieties was suggested.

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Adaptation of the IBM Card System to Analysis of Sugar-Beet Varietal Data

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Introduction

Analyses of sugar beet varietal data require many computations which must be recopied and summarized before the data can be presented in final form. This work is not only time consuming, but the recopying often brings in errors which are difficult to eliminate. The comprehensive and dependable analyses made possible by punched card equipment offer many advantages. Data recorded on a card with permanently punched holes are very flexible. The information can be classified rapidly and transcribed accurately, completely or in part.

A standard IBM card is 3¼ inches wide by 7⅜ inches long with 80 columns and ten vertical positions in each column for recording of numerical

Figure 1.—IBM Card Showing Layout, Interpretation and Typical Punched Card.

information (Figure 1). For alphabetical information two additional vertical positions above the zero are used and each letter is represented by two holes in each column. The significant use of the punched card has been summarized as follows (1):[2]

> "Just as punched holes in a roll of paper can produce music, so punched holes in IBM cards can produce reports. Written records can be read only by the eye, but punched card records can be read by machines as well. Such records are sorted and summarized by machines at higher speed and with greater accuracy than would be possible by any manual process. The cards, therefore, once they are punched and verified, are the basis of all printed reports."

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[2] Numbers in parentheses refer to literature cited.

To study the feasibility of using the IBM card system for analyzing sugar beet varietal data, the facilities at the Utah State Agricultural College were utilized for data obtained in 1950 and 1951. To save trips between the sugar-beet laboratory at Salt Lake City, and Logan, Utah, some of the cards were punched with machines at the University of Utah. The Service Bureau of the International Business Machines Company at Salt Lake City also assisted with some of the work which was paid for on a "job" basis.

Description of Equipment and General Operation

The IBM equipment of the Utah State Agricultural College includes the following machines: 1. card punch, 2. verifier, 3. interpreter, 4. sorter, 5. tabulator or accounting machine, 6. reproducing summary punch, 7. collator, and 8. multiplier. The first seven were used in connection with the sugar beet data. There would be an advantage in having the new IBM statistical machine which sorts and tabulates at the same time, although this machine has its primary use with enumeration rather than measurement data.

1. The card punch machine enables the operator to record data by means of punched holes in the IBM card. This is similar to a typing operation.

2. With the verifier a different operator repeats the punching operation. If a mistake has been made the verifier does not agree with the punched holes, the machine stops and a correction must be made. Cards should always be verified.

3. The interpreter prints information from the punched holes in either of two positions to the upper margin of the card. The present machine is limited to printing 60 digits on a single line and hence the printing cannot be directly above the 80 respective columns (see Figure 1). There is a new punching machine which punches and prints in one operation with smaller print directly above the punched columns.

4. By means of the sorter the cards can be arranged in any order desired providing suitable code numbers have been punched in the card and dials on the machine can show visual card counts at the same time.

5. The tabulator or accounting machine gives either a listing with totals and sub-totals or a tabulation of totals, depending upon how the control panel is wired and the switches set.

6. The reproducing summary punch machine reproduces all or any portion of the punched data from one group of cards to another. This machine also punches totals or sub-totals to new summary cards as recorded by the IBM tabulator. This punch machine may also transfer information from master cards to detail cards and compare the punched results for accuracy. A special device may be added which makes possible the punching of holes from suitable marks made on the card with a special lead pencil.

7. The collator is used in a number of ways. One use is to intersperse summary cards on top of detail card groups so that totals can be "gang-punched" by the reproducing machine into detail cards. This

operation was found particularly useful for punching sub-totals on detail cards for tabulation of "y" and "b" values (2) for obtaining the "W" values (quantities required for the analysis of variance of lattice designs).

8. The multiplier performs many operations which are difficult if not impossible with the other machines described. The usual operations, addition, subtraction and multiplication, in any combination of two or more amounts punched in a single card are readily accomplished by this machine with the answer punched in the same card. Division may also be included with the newer machine, whereas with the older ones division may be done by multiplication with reciprocals.

Analysis of Sugar Beet Data

Most of the sugar beet varietal data were first copied on large sheets of ruled paper numbered to 80 columns, corresponding to the 80 columns of the IBM card. In this way each line represented an IBM card or plot. Balanced lattice designs with 25 varieties were analyzed. The punching and tabulating work for one of these designs was completed in approximately three hours with the equipment at the Utah State Agricultural College. This included five categories or fields of information, number of beets after thinning, number beets harvested, tons per acre, percent sucrose and percent purity. The number of columns for the setup required two sets of cards. The lattice design required a listing by variety with variety and final totals, tabulation by replication, tabulation by block within replication, and accumulated totals for each variety, and tabulation by variety with final totals for y and b values. The W values were calculated from the formula $(y - rb)$ (2). This operation plus calculating all sums of squares required approximately one hour additional work with a conventional calculating machine for each lattice design.

After these tabulations were made for 1951 data some interesting information on sodium content (by use of the Amalgamated Sugar Company's flame spectrophotometer) was obtained for the same varietal material. The IBM Service Bureau at Salt Lake City was able to follow the procedure and tabulate the sodium information. The cost was $18 per hundred cards or a total of $27 for the test involving 150 cards. This included listing each plot of each variety and tabulating the totals together with tabulations for y and b values, as above.

Discussion

The size or the number of experiments controls whether the IBM card system offers an economical method. The sorters can handle 450 to 650 cards per minute and the tabulator 80 to 150 cards per minute. The machines can be adapted to a large number of statistical problems. They can readily be used in the analysis of variance of randomized blocks and Latin-square designs, or for lattice designs, particularly the balanced lattice.

With the use of the IBM machines the biggest problem is to collect the information on the IBM cards. The method which would involve the least copy work would be the best. The most efficient procedure would

be to plan the details from the beginning with punched cards designed for the specific data to be collected. These cards can be pre-punched for each plot and the randomization with restrictions imposed by the design accomplished by the machine, including the detailed printing of the field plan.

Cards for each plot could be pre-punched for each type of data to be taken and used in the field for recording with a graphite pencil directly to the card. This method would eliminate the time-consuming transfer of data and the elimination of errors which invariably creep in when data are copied. Multiple cards per plot create no problem because the machines process the cards rapidly and all data can be brought together from separate cards easily, providing suitable control or identification digits are pre-punched in the cards.

During the past year in many projects at the Utah Agricultural Experiment Station this system has been used with excellent success. The basic plan is to record raw data on cards at the time they are observed and then all subsequent computations and summaries can be completed by machine. This requires careful planning in advance and often provision must be made for recording data which cannot be anticipated.

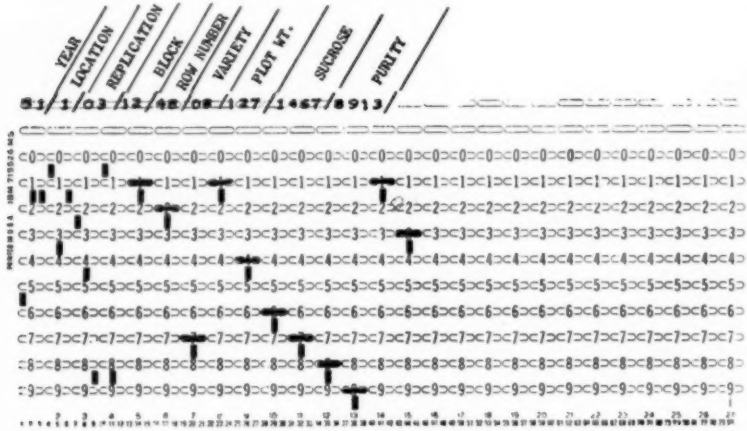

Figure 2.—IBM card showing special graphite pencil marks for plot weight, sucrose and purity. The electrographic pencil marks make it possible for the machine to punch holes corresponding to the penciled data. In the above card the coded information for year, location, replication, block and row number and variety was punched in advance.

If recording directly to cards is not feasible the next best procedure would be to organize the field reports so that the data can be key punched directly from these original records. Once the data have been recorded in the form of punched holes, complete control of accuracy is easily maintained.

Most of the sugar beet varietal data were recopied to the large special sheets of ruled paper with 80 columns corresponding to the 80 columns

on the IBM card. This recopy work, however, requires a good deal of time with corresponding chances for mistakes, but on the other hand it makes the card punching operation simple.

The experimental designs tabulated by Cochran and Cox, pages 304-305 and 360-361 (3), were found to be extremely useful and facilitated the coding of plot data.

The Service Bureau in Salt Lake City was asked for a comparative cost estimate on the lattice design problem with 750 cards (five lattice designs of 150 cards each). The price quoted was $8 per hundred cards. As the number of cards increases, the time required per unit is considerably reduced.

Summary

The advantages of the IBM system in analysis of sugar beet varietal data are greater accuracy with a large saving of time as compared with tedious copy work, sorting and hand recording. The method would be more practical if data from similar experimental designs from several locations could be run at the same time. The time involved in setting up the machines is much greater than that of running additional cards.

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Measurement of the Difference Between "Sugar Type" and "Yield Type" Sugar Beets

ALBERT C. WALKER, LUCILE R. HAC[1] AND CHARLES PRICE[2]

One of the best opportunities for further improvement in the sugar beet crop lies in a better understanding and utilization of the large correlations existing between physiological characteristics of the beet. The general conditions producing correlations between the characteristics of sucrose, glutamic acid and root weight may be formulated as follows: Solar energy absorbed by the beet plant is either utilized in the growth processes or is stored—chiefly in the form of sucrose. Soil nitrogen is likewise absorbed, and either utilized for growth or stored—chiefly in the form of glutamine (which is measured as glutamic acid in the laboratory).

In such a situation, genetic and environmental factors of three general types can be postulated to explain the wide variability observed in these characteristics, namely:

1. Factors altering the balance between growth and storage in the direction of less growth should favor a higher content of both sucrose and glutamic acid.
2. Factors increasing the total amount of energy absorbed should favor both greater size of beet and higher sucrose and glutamic acid content if adequate soil nitrogen is available. If soil nitrogen is inadequate, additional energy would cause glutamic acid to decrease.
3. Factors increasing the amount of nitrogen available to the plant tend to raise glutamic acid and decrease sucrose (1, 2)[3] while increasing growth to a maximum; in the presence of excessive nitrogen, root weight decreases.

The problem here is to evaluate both the size and direction of these factors. Two single factors, e. g., a single gene change and a constant difference in temperature actually might be very different, but would still give results indistinguishable in measurements on sucrose, glutamic acid and weight if they belonged to the same type. Any single factor might give a change intermediate to the three general types but classifiable as effecting a certain amount of change in each type.

One possible approach to a solution of this complicated situation is offered by the use of the discriminant function suggested by R. A. Fisher (3). When a number of concomitant measurements on the same experimental material are available, the discriminant function shows the linear combination of the measurements giving the greatest significance for comparisons among experimental groups. In variety trials on sugar beets, where considerable correlation between the measured quantities is usual, the most significant difference is not obtained in the direction of any one measurement but is in a direction intermediate to the various measurements.

As an example of the use of discriminant functions, a variety trial at Salinas, California, in 1946, was selected. This experiment[4] on 12 varieties of sugar beets originally contained 12 replications, but two of these were

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[3] Numbers in parentheses refer to literature cited.
[4] Experimental work carried out in cooperation with the Spreckels Sugar Company.

deleted for the present calculation because of their unfortunate arrangement in the field. Ten beet samples were taken from each plot for analysis, and portions of the pulp were frozen and analyzed for glutamic acid (2) and sucrose (4) the following spring. Results are shown in columns 1, 2, and 3 of Table 1. Errors in the experiment, as shown by the size of the least difference required for significance, were relatively large due to large variations in fertility, and to inadequate sample size for accurate glutamic

Table 1.—A Comparison of 12 Varieties Tested at Salinas in 1946.

Variety	Sucrose	Glutamic Acid %	Yield Tons/Acre	Storage Potential (X)	Growth Potential (Z)
SL 222 (US22/2)	14.0	.11	29.1	10.1	23
SL 922 (US22)	13.8	.15	28.2	10.9	25
SL 315 (US15)	14.1	.17	28.3	11.3	27
SL 36 (US22/2 Select.)	14.4	.13	28.1	11.5	25
SL 333 (US33)	14.8	.14	28.0	12.0	27
SL 456 (US56)	15.0	.12	27.4	12.6	25
SL 411 (US22/2 Select.)	14.5	.10	26.7	12.7	20
SL 53 (US22/3 Select.)	14.4	.08	25.4	13.6	16
SL 4108 (US22 MS X CT_9)	15.0	.06	25.0	14.4	15
SL 52 (US22/3 Select.)	15.4	.09	25.5	14.7	21
SL 1-300 (Old Type)	15.5	.08	24.0	16.0	19
SL 54 (US35)	15.5	.10	22.6	17.4	20
LSD (5%)	1.2	69%	2.6	2.7	6

Arrangement: Randomized complete blocks with 10 replications
Plots: 4 rows 65 feet long
Samples: 10 beets per plot
Planted April 4, 1946. Harvested October 21-25, 1946.

acid and sucrose determinations. Differences among variety averages barely reached significance (Table 2) for sucrose and glutamic acid but were highly significant for yield. Average stands at harvest were fairly uniform, ranging from 101 (SL 4108) to 121 (SL 52) beets per 100 row feet.

Primary Varietal Difference

Calculation of the major varietal difference present follows the calculation given by Mather (3). A table of mean squares and mean cross products (Table 3) is set up in the usual way. It is then possible to write an equation in the parameter ϕ as follows, the constants of which may be identified in Table 3:

$$\begin{vmatrix} 1.9274(110)-3.5359(11)\phi & -.24408(110)+.40575(11)\phi & -1.9216(110)+9.6587(11)\phi \\ -.24408(110)+.40575(11)\phi & .074801(110)-.15731(11)\phi & .40045(110)-1.7324(11)\phi \\ -1.9216(110)+9.6587(11)\phi & .40045(110)-1.7324(11)\phi & 12.062(110)-40.712(11)\phi \end{vmatrix} = 0$$

This equation is solved for the smallest real root of ϕ by trial and error, yielding the determinant:

$$\begin{vmatrix} 103.36 & -14.381 & 85.409 \\ -14.381 & 3.3944 & -9.1824 \\ 85.409 & -9.1824 & 75.812 \end{vmatrix} = 0; \text{ at } \phi = 2.7934$$

If this determinant has been verified by expanding down the first column the three minors $M_{11} = 173.02$, $M_{12} = -306.01$, and $M_{13} = -157.85$ will be available. The discriminant function maximizing varietal differences is of the form: $X = AS + BG + CW$ where S = % sucrose, G = 1 + log % glutamic acid, and W = tons beets per acre. If A, the coefficient of S, is arbitrarily taken as 1, $B = -M_{12}/M_{11} = 1.8$ and $C = M_{13}/M_{11} = -0.9$. In order to eliminate negative values and give results more comparable

between experiments, the discriminant function is expressed in terms formally equivalent to % sucrose at 0.15% glutamic acid and 25 tons per acre yield by adding the constant —1.8 (1 + log. 0.15) + .9(25) = 22.2. This gives:

$$X = S + 1.8G - 0.9W + 22.2 \qquad \text{Eq. 1}$$

We have called this quantity an estimate of the **storage potential** of the variety. It gives differences more highly significant than the original measurements (sucrose, GA and weight) or any other linear combination of them (Tables 1, 2 and 3). There is a nine percent increase in the F value (Table 2) over the largest individual difference, that of weight. In other experiments carried out at Woodland the advantage of the discriminant function has been usually much greater. Similar equations were obtained maximizing varietal differences in five experiments, in which values of B ranging from 1 to 10 and C ranging from —0.1 to —2.0 were found. Evidently the values of both B and C vary with both the set of varieties chosen and the environmental conditions.

Table 2.—Variance Ratios and Correlation Coefficients.

F Values			Correlation Coefficients			
D.F.	Varieties 11/99	Blocks 9/99	D.F.	Varieties 10	Blocks 8	Error 98
% Sucrose (S)	2.02[1]	10.42[3]	SG	—.50	—.92[3]	—.67[3]
1 + Log % Glutamic Acid (G)	2.40[1]	4.27[3]	SW	—.80[2]	—.55	—.27[2]
Tons per Acre (W)	4.59[3]	3.91[3]	GW	.68[1]	.73[1]	.33[3]
Storage Potential (X)	5.02[3]	6.06[3]				
Growth Potential (Z)	3.66[3]	2.56[1]				
Nitrogen Status (Y)	1.42	8.09[3]				

[1] Exceeds the 5% point of significance.
[2] Exceeds the 1% point of significance.
[3] Exceeds the 0.1% point of significance.

Since small beets with high sugar give large values of storage potential, while large beets with low sugar give low storage potentials, it is evident that this quantity gives a numerical measure of the difference between the "sugar type" and the "yield" or "tonnage type" of sugar beet. The inclusion of a third component, glutamic acid, in this numerical measure has definite advantages because it eliminates confusion of other genetic and environmental effects. On the basis of sucrose and weight, a sugar-type beet grown in high nitrogen soil could not be differentiated easily from a yield-type beet grown in soil of average nitrogen, but its higher glutamic acid and storage potential would distinguish it as a sugar type.

One would predict from equation 1 that high storage potential beets would tend to have high glutamic acid and we have generally found this to be the case. The opposite results shown by the variety averages in the present case appear to have a quite different cause and will be discussed later.

From the initial discussion it appears that an increase in the storage potential, tending to raise sucrose and glutamic acid as weight decreases, is governed by a group of factors tending to divert energy from growth to storage. Since significant effects were observed in both variety and block comparisons, both genetic and environmental factors are operating. It seems quite possible that further measurements, especially one of top weight, might give additional information on the nature of the genetic changes involved.

Table 3.—Mean Squares and Mean Cross Products.

D.F.	Varieties 11	Blocks 9	Error 99	Varieties + Error 110
S^2	3.5359	18.171	1.7486	1.9274
G^2	.15731	.28008	.065633	.074801
W^2	40.712	34.695	8.8783	12.062
SG	—.40575	—2.0634	—.22612	—.24408
SW	—9.6587	—13.767	—1.0620	—1.9216
GW	1.7324	2.2744	.25246	.40045

Secondary Varietal Difference

When more than two measurements are made on a set of data it is clearly possible that secondary maxima in the various possible F values, resulting from different directions of measurement, be present. If it is assumed that the standard deviation constitutes a rational unit of measure for each measurement, it is possible to calculate a second discriminant giving the greatest significance in directions perpendicular to the first discriminant:

Thus if the three variables S, G, and W are each measured from their general mean and a set of discriminant planes

$$X = AS + BG + CW \qquad \text{Eq. 2}$$

has been calculated as above, it can be shown that the line which passes through the origin and which would be perpendicular to X if S, G and W were measured in units of their standard deviations is

$$\frac{S}{AV_S} = \frac{G}{BV_G} = \frac{W}{CV_W} \qquad \text{Eq. 3}$$

where V_S = variance of S, etc. The point of intersection of 2 and 3 gives the expected value of $S\,(=S_E)$ and $G\,(=G_E)$ for given X:

$$S_E = AV_S\ X/K \text{ and } G_E = BV_G\ X/K \qquad \text{Eq. 4}$$

where $K = A^2V_S + B^2V_G + C^2V_W$. The deviations of each measurement of S and G from its expectancy are given by

$$\Delta S = S - S_E = S - AV_S\ X/K \text{ and} \qquad \text{Eq. 5}$$

$$\Delta G = G - G_E = G - BV_G\ X/K$$

Thus the quantities

$$K\Delta S = (B^2V_G + C^2V_W)S - ABV_S G - ACV_S W \text{ and} \qquad \text{Eq. 6}$$

$$K\Delta G = -ABV_G S + (A^2V_S + C^2V_W)G - BSV_G W$$

are proportional to that part of the variation which cannot be attributed to variations in X. A discriminant function can then be calculated which maximizes differences in ΔS and ΔG

$$Z' = K\Delta S + D(K\Delta G) \qquad \text{Eq. 7}$$

Z′ may then be expressed in terms of S, G and W by use of equation 6 and any one of the coefficients of S, G or W given an arbitrary value. This

might give, for example,

$$Z = ES + FG + W \qquad \text{Eq. 8}$$

as the "secondary discriminant" giving the most significant differences perpendicular to the ordinary discriminant function, $X = AS + BG + W$, if S, G and W are measured in units of the standard deviation.

In the present experiment

$$K_\Delta S = 7.5957S - 3.0930G + 1.5954W$$
$$K_\Delta G = -.11609S + 9.1390G + .10592W$$

Analysis of variance and calculation of a discriminant maximizing differences in ΔS and ΔG gives

$$Z' = K_\Delta S + 7.1682\ K_\Delta G$$
$$= 6.7635S + 62.417G + 2.3546W$$

It is convenient to divide by 2.3546, giving

$$Z = 2.9S + 27G + W$$

This equation is made formally equivalent to the weight in tons per acre at 15 percent sucrose and 0.15 percent glutamic acid by adding the constant $-2.9\,(15) - 27\,(1 + \log.\ 0.15) = -48$. Therefore

$$Z = 2.9S + 27G + W - 48 \qquad \text{Eq. 9}$$

This secondary discriminant, perpendicular to the storage potential, is designated **growth potential.** Being characterized by positive coefficients for S, G and W it appears to be a measure of the total "vigor" or energy absorption of the plant. Very significant differences are present among the varieties tested. Strains which have proved to be commercially useful, such as SL 922, 333, 315 and 456, have uniformly a high growth potential. Strains with significantly lower growth potential, especially SL 53 and 4108, would be expected to have no direct commercial value. Low growth potential might be caused by either low innate vigor or low resistance to adverse environmental conditions perhaps peculiar to this experiment.

In this experiment the large coefficient of glutamic acid in the growth potential equation 9 explains why the tonnage-type beets (those with low storage potential) unexpectedly had relatively high glutamic acid. The greater growth potential, tending to increase glutamic acid at adequate nitrogen levels, more than compensated for the low storage potential which tends to divert nitrogen from storage.

In other experiments, the growth potential has been found to be a major component of the environmental variation, so that varietal differences in this direction are not easily measurable. The coefficient of S has been found to vary from 2 to 15, while the coefficient of G has varied from —22 (at very low N) to the present +27.

Residual Independent Variation

If the measured variables in the storage potential and growth potential equations are expressed in terms of their standard deviations ($S' = S/\sigma S$. etc.) the following equations are obtained:

$$X = 1.32S' + 0.45G' - 2.72W' + 22.2 \qquad \text{Eq. 10}$$
$$Z = 3.80S' + 6.79G' + 2.98W' - 48 \qquad \text{Eq. 11}$$

The set of planes perpendicular to these two is

$$Y = -3.56S' + 2.56G' - 1.30W' \qquad \text{Eq. 12}$$

Expressed in ordinary units, this is equal to

$$Y = -2.7S + 10G - .44W \qquad \text{Eq. 13}$$

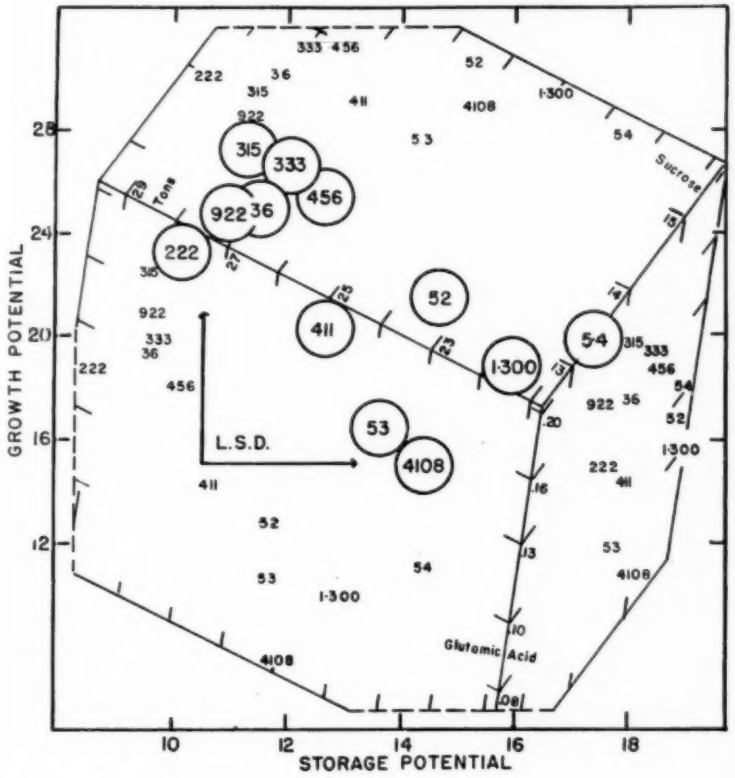

Figure 1.—An orthogonal projection of a three-dimensional graph of varietal averages of sucrose, weight and glutamic acid, viewed from the particular direction showing storage potential and growth potential as perpendicular measurements. Storage potential gives the greatest significance among varietal comparisons, and growth potential gives the greatest significance in the residual variation perpendicular to changes in storage potential. Projections of the varietal averages on the boundary planes are shown as uncircled numbers.

This function is nearly identical with that one found (5) to give the most highly significant difference between levels of applied nitrogen fertilizer and is designated **nitrogen status.** No significant difference in nitrogen status was detectable in the varieties in this experiment. Nitrogen status accounts for a major part of the block variation and presumably of the error variation. Calculation of secondary discriminants and residual independent variation are artifices to be used when the experiment has not incorporated other classifications, the maximization of which can indicate the proper directions of measurement. Thus testing of varieties at two levels of nitrogen, not too widely separated, would permit the direct calculation of nitrogen status. Treatments producing pure changes in storage potential and growth potential have not yet been identified.

Discussion

The transformation of axes from sugar, weight and GA to storage potential, growth potential and nitrogen status which has been carried out by the above calculations is depicted graphically in Figure 1. It is a representation of a three-dimensional graph of the varietal averages viewed in the direction of changing nitrogen status. Such transformation is useful in many ways. It explains why the difference between sugar-type and tonnage-type beets is sometimes manifested chiefly in differences in sugar, and other times, as in this case, in differences in weight. Storage potential, the difference between these different types, is measured with optimum accuracy. The nature of the change in storage potential is shown by solution of the three discriminant functions (equations 1, 9, 13) obtained for weight and glutamic acid at constant growth potential and nitrogen status. This shows that weight increases 4.7 tons for each percent sucrose lost as the beets approach more of a tonnage type. This implies that gross sugar per acre improves as lower storage potential beets are obtained. Similarly, glutamic acid increases 16 percent for each percent sucrose gained as beets approach more in the direction of the true sugar type or high storage potential beets. This relationship may be compared to that found by Skuderna et. al. (6) in a comparison of two European yield-type strains to two European sugar-type strains. The general weighted average showed a gain of 2.59 tons for each percent sucrose lost, while tests in California averaged 4.8 tons for each percent sucrose lost.

Difficulties in the method lie in the absence of a procedure for determining the error of the discriminant function coefficients when differences among more than two varieties are maximized. Results could be unduly affected by choice of varieties studied or the nature of the error encountered. Finally, sampling errors of the standard deviation can affect the direction of any secondary discriminants calculated.

Summary

Methods have been described for calculating the direction of the most significant difference between varieties when measurements on sucrose, weight and glutamic acid are available. Storage potential, the primary discriminant function thus obtained, differentiates between varieties even under conditions of widely varying fertility. Beets of high storage potential are

true "sugar type" with high sucrose, low weight and **high** glutamic acid; those of low storage potential are true "yield type" having low sucrose, high weight and **low** glutamic acid.

High vigor, measured by a secondary discriminant, tends to increase the glutamic acid content of the beet. Varieties with low nitrogen foraging ability are distinguished by high sucrose, low yield and low glutamic acid. A method for calculating a secondary discriminant function perpendicular to the primary one has been developed.

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Sugar Beet Types Based on Internal Morphology

ERNST ARTSCHWAGER[1]

The varieties of sugar beets grown here and abroad present a diversity of forms from the standpoint of leaf and root development, and internal structure. The types identifiable by general appearance and internal morphology may be alike or different. The intravarietal types become fewer with the approach to homozygosity in self fertile lines. This fact was brought to a focus in an earlier study on beet populations (1)[2]. Most of the varieties included in the present investigation[3] show in their internal morphology many aberrant types, but a few of the inbred lines were found to be relatively uniform.

The storage of sugar is an expression of the general metabolism, contingent on structure and subject to external and internal influences. Certain structural configurations favor or preclude sugar storage but actual analyses show that "sugar is where you find it," and that the ideal inner makeup for performance is not the same for all selections. Often apparently antithetical combinations do not preclude a high yield.

Structure of the Storage Root

The inner structure of the sugar beet root is well known; it has been described and illustrated by many investigators. Suffice it to say that the root is composed of concentric rings of vascular tissue alternating with bands of parenchyma (Figure 1A). The inner rings are mature at harvest time, more or less equidistant and relatively broad; those near the periphery are narrow and close together. In fact, in a typical mature beet root, the ratio of total radius of mature to immature rings is 10:1. The center of the beet root is occupied by a solid star-shaped body referred to as the central core. It measures only a few millimeters across but occasionally it is much thicker. Although it is quite uniform throughout its entire length, it may taper abruptly from the neck region downward. This is frequently seen in beets whose central core in the neck region is abnormally large. To distinguish the tapering core from the uniformly thick one it is necessary to check the core diameter at different root levels. The vascular rings are composed of collateral bundles in which xylem and phloem are equally broad or in which the phloem or the xylem is the more massive. The interzonal parenchyma is narrow, broad or varying in width. In the latter case the parenchyma bands between the innermost rings are usually widest.

Type Formulas Based on Internal Structure

The use of floral formulas as a short cut to description is nearly as old as the science of taxonomy. The applicability of such a "shorthand" method of recording, using vegetative characters, seemed indicated. It was successfully tried by the writer in the description of sugarcane varieties, but the description concerned itself only with the stem epidermis. The scheme is now extended to the proposed characterization of sugar beet types based on internal structure. Certain character combinations were found to be diagnostic, often recurring, and in some degree indicative of

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[2] Numbers in parentheses refer to literature cited.

[3] The writer is indebted to G. W. Deming and J. O. Gaskill of the USDA Field Station at Fort Collins, Colo., and to H. L. Kohls of Michigan State College for providing the material used in this study of for making the sugar analyses.

performance. Five characters, each with three variants, are incorporated in the formulas. However, for the complete characterization of a variety additional data on structural peculiarities, color and texture of flesh, number of rings, ring density coefficient and size of central core should be recorded.

For the evaluation of characters used in the construction of the type formulas, the root is studied: 1. by viewing the cut surface of the neck region *in situ*, and 2. by examining a thin cross section of the root against a black background; both examinations are complementary. Examined *in situ*, the exposed surface may be: a. of uniform texture, b. show an indica-

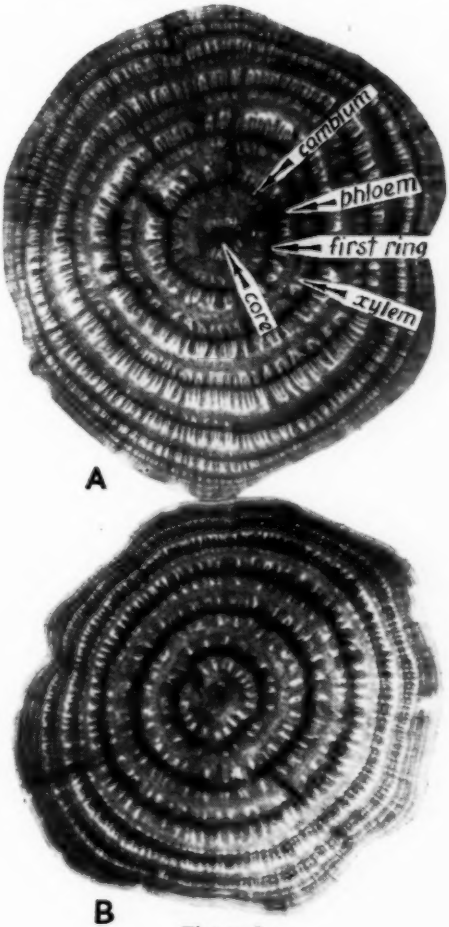

Figure 1.

tion of zonation, c. exhibit a clearly recognizable difference between vascular rings and interzonal parenchyma. Such beets usually have a grayish flesh which may appear translucent or water-soaked. If thin cross sections of the groups listed above are viewed against a black background, structural contrasts become enhanced. Thus, beets of the first group whose cut surface exhibits *in situ* a bland uniformity, reveal in section a typical though faint zonation which becomes quite pronounced in beets of the second class. Beets in the third class show such a wealth of contrast that even minor details in structure are mirrored faithfully.

The cambium of the vascular rings appears as a solid or dotted line, white or light yellow in color. In some beets the adjacent vascular tissue may also be white, giving the appearance of a broad, white cambium zone. Such white bands are commonly observed in the two innermost rings; they are less distinct and usually wanting in the others. Occasionally the white zone is so broad as to encompass most of the vascular tissue. The inter zonal parenchyma of such beets has a translucent appearance which contrasts strongly with the white of the vascular zone.

List of Characters

General appearance of the cut surface *in situ*.

1. Surface mealy white or ivory; zonation faint or absent.
2. Zonation indicated.
3. Zonation pronounced; flesh often gray and translucent.

Appearance of thin cross section against black background.

4. Zonation indicated.
5. Zonation pronounced; rings distinctly set off from interzonal parenchyma.
6. Rings very prominent with limits of phloem and xylem clearly defined.

Width of vascular rings.

7. Rings broad.
8. Rings narrow.
9. Rings variable in width; inner rings characteristically broader.

Width of interzonal parenchyma.

10. Parenchyma bands broad.
11. Parenchyma bands narrow.
12. Parenchyma bands of inner rings conspicuously broader.

Size of first ring.

13. Ring broad with a diameter of 22 mm. or more.
14. Rings medium large.
15. Rings narrow with a diameter of 12 mm. or less.

Type 1.

Origin: Selection SLC 78, U. S. 41.
Formula: 3-6-7-11-14.
Quantitative data: 10 rings; R. D. Coef. 2.0; sucrose 20.1 percent; weight 1.71 pounds.

Remarks: Flesh ivory gray or grayish; prominent white cambium line; small core. This type of internal structure was characteristic of about one-half of all beets studied. Its structural configuration, especially the massive phloem and the narrow bands of interzonal parenchyma, are indicative of high sugar storage. Nevertheless, many low performers fall into this class.

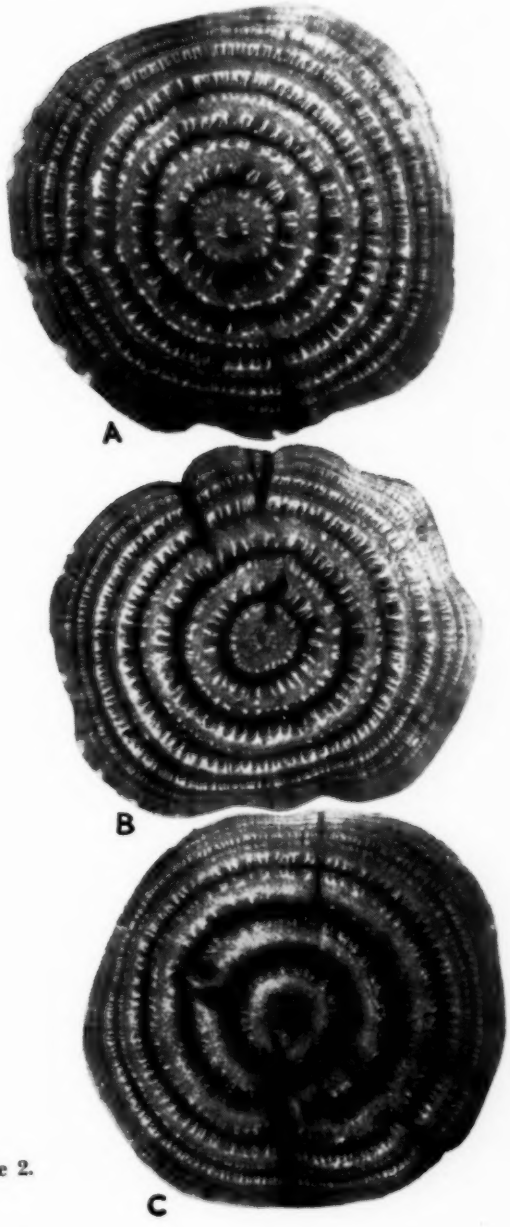

Figure 2.

Type 2.

Origin: Selection 491023-0.
Formula: 3-6-7-12-13.
Quantitative data: 10 rings; R. D. Coef. 1.82; sucrose 16.4 percent; weight 2.48 pounds.

Remarks: This is a fourth generation hybrid between mangel and sugar beet. The radius of the xylem exceeds that of the phloem; core large. The low sugar content is associated with a low R. D. Coef., massive xylem and broad first ring.

Type 3. Figure 1, A

Selection: SL 622, U. S. 22/3.
Formula: 2-6-7-11-13.
Quantitative data: 9 rings; R. D. Coef. 2.0; sucrose 14.5 percent; weight 2.16 pounds.

Remarks: Flesh ivory-cream with narrow white cambium line, massive phloem and medium large core. Indicative of higher sugar content than shown by analysis.

Type 4. Figure 1, B

Selection: SL 622, U. S. 22/3.
Formula: 2-5-8-11-14.
Quantitative data: 11 rings; R. D. Coef. 2.39; sucrose 24.4 percent; weight 1.84 pounds.

Remarks: Fine-grained ivory-white flesh; bundles within rings widely spaced; inner rings with broad white cambium; core small. The exceedingly high sugar content of this beet is associated with a high ring density coefficient, medium broad rings, and a very uniform fine-grained flesh.

Type 5. Figure 2, A

Selection: SLC 824, U. S. 35/2.
Formula: 2-6-8-12-14.
Quantitative data: 11 rings; R. D. Coef. 2.44; sucrose 17.4 percent; weight 1.37 pounds.

Remarks: Flesh white-ivory or cream; medium broad white cambium zones; small core. Indicative of higher sugar content than shown by analysis.

Type 6. Figure 2, B

Selection: SLC 78, U. S. 41.
Formula: 2-5-9-12-14.
Quantitative data: 10 rings; R. D. Coef. 2.44; sucrose 18.8 percent; weights 1.52 pounds.

Remarks: Flesh ivory-cream; broad white cambium zones, very small core; High R. D. Coef. indicative of higher sugar content than indicated by analysis.

Type 7.

Selection: U. S. 215x216/3.
Formula: 1-4-8-10-13.
Quantitative data: 9 rings; R. D. Coef. 1.95; sucrose 13.7 percent; weight 1.43 pounds.

Remarks: White flesh; large core. Low sugar content is associated with a low R. D. Coef., broad first ring and broad bands of interzonal parenchyma.

Type 8.

Selection: SL 622, U. S. 22/3.
Formula: 1-4-8-10-15.
Quantitative data: 10 rings; R. D. Coef. 2.0; sucrose 21.4 percent; weight 1.93 pounds.

Remarks: White-ivory flesh; white broad cambium zones; very small core. This type is very similar to type 7, but the sugar content is much higher.

Type 9.

Origin: Strain 1503 from U. S. 30297-0. 1936 root selfed once. 1951 beets sixth generation: self, self, self, self, sib (group 3), self.
Formula: 2-5-8-10-14.
Quantitative data: 9 rings; R. D. Coef. 2:14; sucrose 16.4 percent; weight 2.05 pounds.

Remarks: Cream-colored flesh, narrow sharply defined cream-orange cambium; narrow bundles, broad interzonal parenchyma; large core and broad first ring.

Type 10. Figure 2, C

Selection: SLC 835, U. S. 35.
Formula: 1-4-8-10-13.
Quantitative data: 8 rings; R. D. Coef. 2.0; sucrose 18.4 percent; weight 1.48 pounds.

Remarks: Coarse flesh; gray translucent parenchyma; prominent white cambium zones; radius of phloem only slightly larger than that of xylem; large core. Structural configuration indicative of a much smaller sugar content than shown by analysis.

The following three types were selected from highly inbred lines sent to me by H. L. Kohls of Michigan State College. The type formulas are rather constant for all beets in a selection except for variation in size of core and first ring. Because of great differences in root size and shape, determination of the R. D. Coef. could not be made. Individual sugar analyses were not available and the percentage of sucrose quoted represents the average for the group as a whole.

Type 11.

Origin: Selection 57305. East Lansing, Mich.
Formula: 1-4-8-10-13.
Quantitative data: 9 rings; average core 3.8 mm.; average first ring 21.7 mm.; sucrose 15.3 percent.

Remarks: White or ivory flesh of fine texture; indistinct zonation even in section when viewed against a black background; formula constant but much variation in size of core and first ring.

Type 12.

Origin: Selection 624710; East Lansing, Mich.
Formula: 1-4-9-12-14.
Quantitative data: Average ring number 10.3; core 3.7 mm., first ring 16.1 mm.; sucrose 17.0 percent.

Remarks: Grayish vascular rings fading into darker gray interzonal parenchyma; white dotted cambium line. The higher sugar content of this type compared to type 11 is associated with a higher ring number and a smaller first ring.

Type 13.

Origin: Selection 416003. East Lansing, Mich.
Formula: 1-(4 + 5)-9-12-13.
Quantitative data: Average ring number 8.4; core 3.8 mm., first ring 19.6 mm.; sucrose 15.64 percent.

Remarks: Flesh ivory-cream, occasionally grayish; bundles within rings in discrete groups, white solid or dotted cambium line. Formula fairly constant for all roots in the selection; core and first ring very variable.

Constancy and Stability of Characters.

A character to be acceptable should be constant, well defined and stable. Most of the types illustrated in this paper come from heterozygous populations; their characters meet only the second requirement. A study of eight highly inbred Michigan lines shows that almost all characters used in the construction of the type formulas are constant and stable. There is still much intravarietal variation in the size of the core and the first ring which may be genetic or environmental in origin. But even in regard to these characters definite tendencies are indicated. Thus, in selection 57305, the average size of the first ring for 25 individuals is 21.7 mm., while in selection 624710 the first ring measures only 16.1 mm. across.

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Effect of Bolters on Yield and Sucrose Content of Sugar Beets

R. T. Nelson and G. W. Deming[1]

In the growing of a commercial crop of sugar beets, the occurrence of seed stalks has long been considered undesirable. Usually the grower will instruct labor used in weeding the crop to break off any bolters present. Bolters in this case refer to both true and simulated seed stalks. The reasons for objecting to bolters in the commercial crop of sugar beets have not been well defined. One reason frequently given, however, is that bolting reduces root yield. An inquiry into the degree of reduction prompted the studies here reported.

Condensed in this paper are comparative data on yield and sugar content of roots from bolted and non-bolted (normal) plants of sugar beets as gathered on separate occasions at Fort Collins and Longmont, Colo.

Experimental Procedure and Results (Fort Collins)

The results were gathered in the year 1938 in conjunction with a date of planting test which included four sugar beet varieties. Beets from the border rows of the early planted plots were used for the bolting study. Bolting on these plots became evident soon after thinning. Normal beets and bolters of the following types were taken of hybrid 37-304 in such manner as to maintain identity of the type and relative positions of the beets harvested. The types as originally grouped were:

1. Early bolters; seed stalk and seed production comparable to second year growth.
2. Late bolters; more or less leafy seed stalks with bloom and some late seed production.
3. Very late bolters; short leafy seed stalk, no bloom.
4. Mixed bolters; one or more seeded stalks from low side buds, but main crown of beet nearly normal.
5. Normal, adjacent to each of above types of bolters.
6. Normal, second adjacent to each of above types of bolters.
7. Normal, third plant or more removed from each of the above types of bolters.

Preliminary examination of root weights indicated that Groups 2, 3 and 4 did not materially differ and therefore these groups were combined to form the late bolter group as presented in Table 1.

Table 1.—Mean Root Weight, Including Crown, of Paired Samples from Hybrid 37-304 and Calculated P Value for Likeness of Paired Means. Fort Collins, Colo. 1938.

Groups compared	Weights, respectively		Number of pairs	Probablity
	Pounds	Pounds		
Early bolter and 1st adjacent normal	.616	1.356	76	$P < .01$
1st adjacent and 2nd adjacent normal	1.342	1.296	64	$P > .6$
1st adjacent and 3rd adjacent normal	1.318	1.280	29	$P > .8$
Late bolter and 1st adjacent normal	1.271	1.322	95	$P > .5$
1st adjacent and 2nd adjacent normal	1.399	1.391	81	$P > .9$
1st adjacent and 3rd adjacent normal	1.357	1.420	42	$P > .6$

[1] Agronomists, Experiment Station, the Great Western Sugar Company, Longmont, Colo., and Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, respectively.

The data in Table 1 show that the only measurable effect on yield was the reduction in root size associated with early bolting. Subsequent to weighing the roots individually and analyzing the data statistically, using paired comparisons, the beets were topped (crowns cut off at lowest leaf scar), regrouped and reweighed for further comparisons. Sucrose percentage and apparent purity were determined for each group. From the average beet weights, yields in tons of beets per acre were calculated by using the theoretical plant population for 10 x 20 inch spacing. The data are summarized in Table 2.

Table 2.—Yield, Quality and Sugar Percentage for Groups of Bolting and Non-bolting Beets in Hybrid 37-304, Fort Collins, Colo. 1938. (Data Given as 2-plot Averages.)

Groups	Tons per acre	Sucrose percent	Coefficient of apparent purity	Gross pounds sugar per acre
Early bolters	7.90	11.5	90.0	1,820
Late bolters	15.66	12.4	90.6	3,934
Mixed bolters	18.56	12.6	91.5	4,698
Normal adjacent to early bolter	18.78	13.4	90.2	5,042
Normal, 3 or more plants removed from early bolter	17.31	13.4	91.3	4,624
General mean	15.64	12.67	90.73	4,023
L.S.D. 5% pt.	2.90	NS[1]	NS[1]	908

[1] Not significant by Z test.

Obscrvations on the varieties Original Normal (German seed) and Great Western as made in connection with the date of planting test revealed a limited number of bolted plants. Weights and sugar analyses tabulated on these varieties followed the trend established for the hybrid variety reported in Tables 1 and 2.

An ample number of bolters were available for study in the variety U. S. No. 217. Thus, five groups of beets were taken from each of four replications, and a complete analysis made of this variety. The results are summarized in Table 3.

Table 3.—Yield, Quality and Sugar Production for Groups of Bolting and Non-bolting Beets in the Variety U. S. No. 217. Fort Collins, Colo. 1938. (Data Given as 4-plot Averages.)

Group	Tons per acre	Sucrose percent	Coefficient of apparent purity	Gross pounds sugar per acre
Early bolters	12.52	14.25	88.60	3,560
Late bolters	20.73	14.58	90.35	6,043
Very late bolters (Leafy, no seed)	20.36	14.95	89.08	6,078
Normal adjacent to early bolter	20.22	14.95	89.70	6,049
Normal, 3 or more plants removed from bolter	20.44	14.78	89.98	6,031
General mean	18.85	14.70	89.54	5,552
L. S. D. 5% pt.	3.10	NS[1]	NS[1]	834

[1] Not significant by Z test.

Results given in Table 3 correlate with previous tables in that the root yield of early bolters was much reduced. In Table 2 there is an indication that sucrose percentage is adversely affected by early bolting and in Table

the coefficient of apparent purity is marginally lower for the early bolter group. Considering these two factors there is a definite suggestion that early bolting reduced processing quality of the beet as well as yield.

Experimental Procedure and Results (Longmont)

During the 1951 growing season bolters were prevalent (3-4 percent) on one field of commercial sugar beets on the Experiment Station of the Great Western Sugar Company. This field was planted April 3, with seed of variety GW304. Hand labor was used in thinning, which was completed May 29. Bolters became conspicuous shortly thereafter. All bolters were left undisturbed until August 9 when 150 bolted plants were marked by placing stakes adjacent to the plant and the bolters broken off near the ground. These bolters were selected in locations where two or more bolters occurred within six feet of each other. Harvest of 15 samples of 10 beets per sample was made October 8 of groups A, B and C. A similar harvest was made November 7 of groups D, E and F. The groups as classified:

A. Early bolters; undisturbed until harvest.
B. Early bolters; stalks broken off near ground August 9.
C. Normal; beets not bolted.
D. Early bolters; produced seed.
E. Medium bolters; leafy stalk, no seed.
F. Normal; beets not bolted.

Table 4.—Root Yield, Sugar Content, and Sugar Production for Groups of Bolters and Non-bolters Harvested October 8. Longmont, Colo. 1951. (Data Given as 15-sample Averages.)

Group	Tons per acre	Sucrose percent	Pounds sugar per acre
A. Early bolters	12.27	14.95	3,669
B. Early bolters, stalks broken off Aug. 9	11.19	10.70	2,395
C. Normal non-bolters	18.26	15.07	5,504
General mean	13.91	13.57	3,856
LSD 5% pt.	1.63	.57	480
LSD 1% pt.	2.20	.77	647

The 10 beets composited for each sample of the three groups harvested on the same day were taken within as compact an area as possible. Crown tissue was trimmed off to the lowest leaf scar. Roots of each 10-beet sample were washed and clean weights and sucrose percentage obtained. The data summarized in Table 4 and 5 were analyzed statistically as a randomized

Table 5.—Root Yield, Sugar Content, and Sugar Production for Groups of Bolters and Non-bolters Harvested November 7. Longmont, Colo. 1951. (Data Given as 15-sample Averages.)

Group	Tons per acre	Sucrose percent	Pounds sugar per acre
B. Early bolter, seeded	11.86	15.47	3,669
E. Medium bolters, no seed	24.02	15.53	7,461
F. Normal, non-bolters	21.90	16.17	7,082
General mean	19.26	15.72	6,071
LSD 5% pt.	2.58	.34	823
LSD 1% pt.	3.48	.46	111

complete block experiment with three treatments and 15 replications. Yield per acre was calculated from the mean individual root weights, using 20,000 beets per acre as the average stand.

Tables 4 and 5 again reveal low yields for early-bolting beets which produce true seed stalks. Breaking the bolters off at a late date and near the ground level caused serious defoliation which was reflected by a low sugar content, (Table 4). The early-bolting, seed-bearing beets are hard and woody making topping and handling operations difficult. Without special care during hand or machine harvest, it is likely that most beets of the early-bolting type would be abandoned in the field.

Summary

Several comparisons, including different varieties of sugar beets, showed that early-bolting plants which formed true seed stalks produced only about one-half the yield of roots of normal plants. Root yields of leafy-type bolting plants which produced no seed and late-bolting plants which bloomed, but produced little or no seed, were comparable to root yields from normal plants.

The sucrose percentage and the coefficient of apparent purity determined on roots from bolting plants were either no lower, or only slightly lower, than for adjacent normal plants.

Bolters left undisturbed in the field did not affect the yield or sucrose percentage of adjacent normal plants. Neither was root yield of bolting plants improved by the practice of breaking off the seed stalks. A lower sucrose percentage was obtained on the roots of bolting plants from which the seed stalks were broken off. This suggests that there is danger of excessive defoliation if this practice is followed during the growing season.

Report of the 1951 Evaluation Tests of Leaf Spot and Black Root-Resistant Sugar Beet Varieties of the United States Department of Agriculture

G. H. Coons, Dewey Stewart, H. W. Bockstahler, G. W. Deming, J. O. Gaskill, J. G. Lill and C. L. Schneider[1]

Agronomic evaluation tests were conducted in 1951 with: 1. hybrids produced by mating U. S. 216 MS and U. S. 225 MS with U. S. 226 and with a somewhat similar synthetic variety made from combinations of four inbred lines; 2. with a synthetic variety, and 3. with selections for black root resistance made from SP leaf spot-resistant varieties.[2]

Tests at a total of seventeen locations were conducted by members of this Division in cooperation with State Agricultural Experiment Stations and by cooperators in the sugar beet industry. The cooperators in research organizations of the industry who contributed data are H. E. Brewbaker and H. L. Bush, Great Western Sugar Company (tests at Longmont and Fort Morgan, Colorado); C. E. Cormany and D. F. Peterson, Holly Sugar Corporation (test at Torrington, Wyoming); C. W. Doxtator, American Crystal Sugar Company (test at Mason City, Iowa); B. E. Easton, Canada and Dominion Sugar Company (test at Wallaceburg, Ontario), and Perc A. Reeve, Farmers and Manufacturers Beet Sugar Association (tests at Indiantown and Saginaw, Michigan).

The varieties in the agronomic evaluation tests were as follows:

SP 491704-02	U. S. 225 (MS) x U. S. 226
SP 501712-02	U. S. 225 (MS) x Syn. Var. (Lines A, B, U, S)
SP 501800-00	Synthetic Variety
FC Acc. 1170 (WC 0200)	Increase of 49A11-00 Black Root Resistant Selection
FC Acc. 1173 (WC 0203)	Increase of EL 1005 Black Root Resistant
FC Acc. 1177 (WC 0316)	Increase of 48B3-00 Black Root Resistant
SP 486-0	Synthetic Check (European types)
"Local"	Supplied by cooperators. At Eaton, Fort Collins, Longmont, Fort Morgan the local was GW 304-50A; at Torrington, Holly 0122-0; at Mason City, Ia. and Stewart, Minn., Amer. Cryst. 3 LSR. Tests in Mich., Ohio, and Ontario used U. S. 216 x 226 Com'l. as "local."

Cercospora leaf spot was severe enough to permit leaf spot readings to be made at Fort Collins (sprinkler) and Fort Morgan; at Wallaceburg, leaf spot over the entire field was about "1," while the European Check averaged about "3." (Rating disease on scale from 1 to 5). In the two Colorado tests in which the susceptible variety (synthetic check) read 6.1

[1] Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration.

[2] Investigations on leaf spot resistance are conducted in cooperation with the Colorado Agricultural Experiment Station, and with various beet sugar companies.

and 6.3, respectively, on a scale 0-10, its yield of sugar per acre was significantly below that of the resistant varieties. In these tests with leaf spot a factor, the three federal leaf spot-resistant varieties did not differ significantly in productiveness among themselves but probably were significantly better than the three varieties, Accessions 1173, 1174 and 1177, in which resistance to leaf spot and black root were combined. In one test, the black root-resistant varieties were superior to synthetic check in production of sugar. High bolting tendency as shown by certain of these strains in March and early April planting in Colorado was responsible for the poor showing, especially of Accession 1177, the increase of 48B3-00. These black root-resistant varieties did not bolt seriously in other tests.

The season, in the main, was one in which the evaluations were chiefly on productivity in absence of serious leaf spot or black root exposure, with the exceptions of the leaf spot influence at Fort Collins and Fort Morgan already noted, and the black root in a portion of the field at Stewart, Minnesota, and at Latty, Ohio. At Stewart, only one variety was significantly better than local, and none were significantly better or worse than general mean. At Latty, Ohio, the three leaf spot-black root-resistant varieties were significantly better than all other varieties. They did not differ significantly among themselves.

As has been pointed out previously, leaf spot-resistant varieties and the leaf spot-black root-resistant varieties may not show superiority over susceptible types unless disease exposures occur. Synthetic check, by its excellent performance in many tests in which disease was not a factor, demonstrated this again in 1951 as it has repeatedly in other years. At the same time, the comparisons as made with as highly productive yield type as synthetic check has proved to be, indicate that the varieties being tested and the local varieties included are not innately non-productive. Superiority in one test or another over synthetic check has usually been traceable to enhanced disease resistance.

U. S. 226, a synthetic of eight inbred lines, taken as standard in 1949, was not used as such but appeared only as the pollinator in two varieties, 491704-02 and the local variety used in Michigan, Ohio, and Ontario tests, U. S. 216 x 226 Com'l. The first-named as an average of seventeen tests was 107.9 percent of synthetic check taken as 100 percent in sugar production in 1950, and in 1951, 104.0 percent. Highest yielding federal variety was 501712-02, produced by pollinating U. S. 225 MS with a synthetic made of the inbred lines A, B, U, S. In terms of synthetic check, it was 104.7 percent in sugar production as an average of all tests. It should be noted that these varieties are hybrids produced by using the male sterile phase of some leaf spot-resistant inbred as the female parent. At present stage of development, the male steriles do not give 100 percent of white anther plants—that is, some pollen producers remain in the populations. Thus, U. S. 225 MS in counts at Beltsville, Md., showed slightly less than 85 percent white anther plants. The performance of a given seed lot may be considerably influenced by the relative percentages of hybrids and sibs in the variety.

Data on sugar per acre, root yield, and sucrose are summarized in Tables 1, 2 and 3.

Table 1.—Acre-Yields[1] of Gross Sugar in Agronomic Evaluation Tests: 1951.

Location	Reported by	491704-02	501712-02	501800-00	Acc. 1170	Acc. 1173	Acc. 1177	486-0 Syn Ch	Local[2]	Gen. Mean	LSD Odds 19:1
Colo.—Eaton	Gaskill; Elder	5,788	6,048	5,778	5,421	5,842	5,534	5,888	6,332	5,829	250 Est.
Fort Collins (Spr)	Gaskill; Elder	2,855	2,717	2,679	2,166	2,477	2,412	2,199	2,833	2,542	225 Est.
Fort Collins (Col)	Deming; Kintzley	6,484	6,504	6,703	5,431	6,219	6,209	6,440	6,771	6,345	459
Fort Morgan	Brewbaker; Bush	7,833	8,043	7,650	7,070	7,308	7,152	7,047	7,996	7,466[3]	310
Longmont	Brewbaker; Bush	8,949	9,122	8,602	7,974	8,467	7,075	9,207	8,996	8,633[4]	522
Wyo.—Torrington	Cormany; Peterson	5,990	5,896	5,917	5,397	5,846	5,761	5,731	5,530	5,758	438
Iowa—Mason City	Doxtator	5,731	6,136	5,485	5,310	5,585	5,538	5,936	6,110	5,729	413
Minn.—Stewart	Schneider	5,099	5,136	5,024	5,281	5,388	5,612	5,092	4,992	5,203	607
Mich.—E. Lansing	Lill	4,821	5,123	4,751	4,610	4,581	4,646	5,255	4,387	4,772	219
E. Lansing	Davis	4,324	4,558	4,050	4,339	4,681	4,419	4,230	4,142	4,391[5]	542
Merrill	Lill	6,486	6,693	6,102	6,137	6,661	6,413	6,546	5,964	6,375	382
Indiantown	Reeve (Krabbe Farm)	5,804	5,666	5,873	5,507	5,494	5,786	5,510	5,450	5,636	435
Indiantown	Reeve (Reinsch Farm)	5,332	4,761	4,712	4,260	4,419	4,580	5,427	4,411	4,738	436
Saginaw	Reeve (Rader Farm)	6,067	6,261	5,816	5,640	5,782	5,845	5,412	5,578	5,800	590
Ohio—Latty	F&M; Lill	3,942	3,896	4,015	4,517	4,589	4,560	3,945	3,804	4,159	308
Fremont	F&M; Lill	4,598	4,556	4,434	4,309	4,892	4,216	3,881	4,492	4,422	557
Ont.—Wallaceburg	Easton	7,828	7,445	7,319	6,733	7,545	6,720	6,375	7,001	7,121	589
Mean of all tests		5,761	5,798	5,583	5,300	5,634	5,434	5,537	5,576	5,583	
Mean of tests in Mich., O., Ont.		5,467	5,440	5,230	5,117	5,405	5,242	5,176	5,025	5,268	

[1] Data given as six-plot averages at Longmont and Fort Morgan; all other tests given as eight-plot averages.
[2] Local in Colo. was GW 304-50A; in Wyo., Holly 0122-0; in Iowa and Minn., Amer. 3LSR; all others, U. S. 216 x 226 Com'l.
[3] Test included GW 59-45R which yielded 7,077 pounds.
[4] Test included GW 59-45R which yielded 9,309 pounds.
[5] Test included 491604-01 which yielded 4,776 pounds.

Table 2.—Acre-Yields[1] of Roots in Agronomic Evaluation Tests: 1951.

Location	Reported by	491704-02	501712-02	501800-00	Acc. 1170	Acc. 1173	Acc. 1177	486-0 Syn Ch	Local[2]	Gen. Mean	LSD Odds 19:1
Colo.—Eaton	Gaskill; Elder	18.20	18.78	17.77	16.69	17.51	16.92	18.30	18.85	17.88	1.00
Fort Collins (Spr)	Gaskill; Elder	11.05	10.67	10.25	8.88	9.59	9.60	9.29	10.74	10.01	1.00
Fort Collins (Col)	Deming; Kintzley	21.43	21.63	21.16	17.82	20.04	20.22	20.46	21.52	20.54	1.13
Fort Morgan	Brewbaker; Bush	22.47	22.81	21.82	20.05	20.21	20.18	21.10	22.91	21.38[3]	0.81
Longmont	Brewbaker; Bush	25.04	25.02	23.79	22.25	22.34	19.47	24.91	24.96	23.69[4]	1.43
Wyo.—Torrington	Cormany; Peterson	18.26	17.55	17.96	15.90	17.15	16.95	16.79	16.45	17.13	1.21
Iowa—Mason City	Doxtator	18.39	20.01	17.49	16.94	17.76	17.57	18.96	19.00	18.27	1.21
Minn.—Stewart	Schneider	17.80	17.74	17.34	18.05	18.37	18.68	16.44	16.50	17.62	1.78
Mich.—E. Lansing	Lill	14.27	15.06	13.82	13.29	13.04	13.32	14.58	12.53	13.74	0.57
E. Lansing	Davis	14.00	14.39	13.19	14.00	14.37	13.61	12.79	12.88	13.73[5]	1.68
Merrill	Lill	21.15	21.97	19.71	20.06	21.04	20.16	20.78	18.88	20.47	1.23
Indiantown	Reeve (Krabbe Farm)	16.51	16.04	16.57	15.31	15.08	15.87	15.31	15.54	15.78	1.09
Indiantown	Reeve (Reinsch Farm)	14.87	13.38	13.11	11.71	11.93	12.41	14.43	12.22	13.01	1.22
Saginaw	Reeve (Rader Farm)	17.72	18.19	17.28	16.17	16.51	16.66	15.83	15.93	16.79	1.55
Ohio—Latty	F&M; Lill	10.15	10.15	10.34	11.33	11.39	11.32	10.08	9.79	10.57	0.67
Fremont	F&M; Lill	12.48	12.39	12.26	11.76	13.02	11.23	10.53	12.24	11.99	1.48
Ont.—Wallaceburg	Easton	21.32	20.29	19.73	18.14	19.57	18.22	17.03	18.85	19.14	1.28
Mean of all tests		17.36	17.42	16.68	15.79	16.43	16.02	16.33	16.46	16.57	
Mean of tests in Mich., O., Ont.		15.83	15.76	15.11	14.64	15.11	14.75	14.60	14.32	15.02	

[1] Data given as six-plot averages at Longmont and Ft. Morgan; all other tests given as eight-plot averages.
[2] Local in Colo. was GW 304-50A; in Wyo., Holly 0122-0; in Iowa and Minn., Amer. 3LSR; all others, U. S. 216 x 226 Com'l.
[3] Test included GW 59-45R which yielded 16.93 tons.
[4] Test included GW 59-45R which yielded 25.45 tons.
[5] Test included 491604-01 which yielded 14.30 tons.

Table 3.—Sucrose Percentages[1] in Agronomic Evaluation Tests: 1951.

Location	Reported by	491704-02	501712-02	501800-00	Acc. 1170	Acc. 1173	Acc. 1177	486-0 Syn Ch	Local[2]	Gen. Mean	LSD Odds 19:1
Colo.—Eaton	Gaskill; Elder	15.86	16.07	16.22	16.20	16.65	16.32	16.05	16.76	16.27	0.50 Est.
Fort Collins (Spr)	Gaskill; Elder	12.92	12.72	13.04	12.19	12.92	12.58	11.81	13.16	12.67	0.50 Est.
Fort Collins (Col)	Deming; Kintzley	15.13	15.03	15.80	15.21	15.51	15.37	15.74	15.72	15.44	0.62
Fort Morgan	Brewbaker; Bush	17.43	17.63	17.53	17.63	18.08	17.72	16.70	17.45	17.46[3]	0.36
Longmont	Brewbaker; Bush	17.87	18.23	18.08	17.92	18.95	18.17	18.48	18.02	18.22[4]	0.50
Wyo.—Torrington	Cormany; Peterson	16.41	16.81	16.48	16.99	17.04	17.02	17.05	16.81	16.83	0.47
Iowa—Mason City	Doxtator	15.56	15.36	15.69	15.74	15.78	15.76	15.65	16.08	15.70	0.31
Minn.—Stewart	Schneider	14.23	14.46	14.49	14.61	14.72	15.04	15.46	15.07	14.76	0.75
Mich.—E. Lansing	Lill	16.89	17.02	17.18	17.34	17.56	17.44	18.02	17.51	17.37	0.43
E. Lansing	Davis	15.36	15.84	15.38	15.46	16.28	16.28	16.52	16.08	15.98[5]	0.71
Merrill	Lill	15.34	15.22	15.48	15.29	15.82	15.91	15.76	15.79	15.58	0.44
Indiantown	Reeve (Krabbe Farm)	17.55	17.68	17.72	18.00	18.16	18.24	17.98	17.54	17.86	0.47
Indiantown	Reeve (Reinsch Farm)	17.94	17.79	18.00	18.19	18.55	18.42	18.81	18.10	18.22	0.32
Saginaw	Reeve (Rader Farm)	17.11	17.20	16.84	17.42	17.49	17.54	17.01	17.50	17.26	0.48
Ohio—Latty	F&M; Lill	19.31	19.11	19.34	19.89	20.16	20.11	19.49	19.31	19.59	0.55
Fremont	F&M; Lill	18.41	18.36	18.09	18.31	18.82	18.73	18.50	18.34	18.45	0.44
Ont.—Wallaceburg	Easton	18.35	18.32	18.59	18.51	19.26	18.46	18.69	18.52	18.59	0.76
Mean of all tests		16.57	16.64	16.70	16.76	17.16	17.01	16.92	16.93	16.84	
Mean of tests in Mich., O., Ont.		17.36	17.39	17.40	17.60	18.01	17.90	17.86	17.63	17.66	

[1] Data given as six-plot averages at Longmont and Ft. Morgan; all other tests given as eight-plot averages.
[2] Local in Colo. was GW 304-50A; in Wyo., Holly 0122-0; in Iowa and Minn., Amer. 3LSR; all others, U. S. 216 x 226 Com'l.
[3] Test included GW 59-45R which yielded 16.93%.
[4] Test included GW 59-45R which yielded 18.28%.
[5] Test included 491604-01 which yielded 16.69%.

Table 4.—Acre-Yields of Sugar and of Roots, Together with the Sucrose Percentages Obtained in Three Randomized Block Tests (12 Varieties, 8 Replications) in 1951, at the Following Locations: A. Gremel Farm, Saginaw, Mich. (P. A. Reeve); B, Kauser Farm, Latty, Ohio (J. G. Lill); C, Duvall Farm, Erie, Mich. (H. W. Bockstahler).[1] (Results given as eight-plot averages.)

Sugar Per Acre	Acc. 1170	Acc. 1171	Acc. 1173	Acc. 1174	Acc. 1177	50B3-0	50A2-00	50A4-00	50A7-00	50104-0	Acc. 1178	US 216 x 226	LSD Odds 19:1
Test A	7,518	7,533	7,794	6,798	7,741	8,080	8,231	8,214	7,932	6,904	6,620	7,524	604
Test B	4,057	4,123	3,939	3,786	4,391	4,670	4,547	4,652	4,856	3,358	2,026	3,088	478
Test C	2,780	2,381	2,468	2,227	2,547	2,764	2,400	2,616	2,887	2,060	1,154	1,737	430
Mean	4,785	4,679	4,734	4,437	4,893	5,172	5,059	5,161	5,225	4,107	3,267	4,116	
Acre-Yield of Roots													
Test A	20.79	20.70	21.21	19.21	21.52	22.09	22.74	22.27	21.88	20.03	18.38	20.99	1.77
Test B	10.28	10.37	9.92	9.63	11.01	11.68	11.56	11.66	12.27	8.82	5.17	7.92	1.20
Test C	8.17	7.01	7.19	6.67	7.54	8.25	7.50	7.92	8.89	6.34	3.47	5.34	1.95
Mean	13.08	12.69	12.77	11.84	13.36	14.00	13.93	13.95	14.35	11.73	9.01	11.42	
Sucrose Percentage													
Test A	18.09	18.20	18.39	17.71	18.02	18.31	18.10	18.42	18.16	17.15	18.08	17.92	0.49
Test B	19.70	19.91	19.86	19.62	19.89	19.99	19.66	19.97	19.76	18.99	19.35	19.43	0.56
Test C	16.96	16.94	17.17	16.75	17.04	16.64	16.11	16.44	16.26	16.31	16.40	16.22	NS
Mean	18.25	18.35	18.47	18.03	18.32	18.31	17.96	18.28	18.06	17.48	17.94	17.86	

[1] Conducted in cooperation with Farmers & Manufacturers Beet Sugar Association.

The performance of the three varieties (Accessions 1170, 1173 and 1177) that combine a considerable degree of black root resistance with leaf spot resistance is extremely promising.[3] Conditions in the humid area did not present the usual black root exposure except as has been noted for the test at Latty, Ohio. Three special 12 x 8 tests at Saginaw and Erie, Michigan, and Latty, Ohio, were conducted in cooperation with the Farmers and Manufacturers Beet Sugar Association. (Tests A, B and C of Table 4.)

These tests included the three black root-resistant varieties of the 8 x 8 tests and six other varieties selected for black root resistance from the leaf spot-resistant strains of the Division. The black root-resistant varieties in the 12 x 8 tests were as follows: Accessions 1170, 1171, 1173, 1174 and 1177, selected in 1947, or 1948, and SP varieties 50B3-0, 50A2-00, 50A4-00 and 50A7-00, selected in 1949. The "50" varieties had one more selection than the earlier ones that have now been directly increased and are designated as "Accessions."

A variety in which curly top resistance and leaf spot resistance are combined, SP 50104-0, was also included in the test. It had had no selection for black root resistance, but one parent in the original hybridization—U. S. 216—would confer some resistance. As a susceptible check, Acc. 1178, "Line U," was included. It will be noted that this inbred line is highly productive when black root (*Aphanomyces cochlioides*) is not a factor, but was strikingly depressed in yield in these tests.

As check variety and to relate the 12 x 8 tests with the 8 x 8 series, U. S. 216 x 226 Com'l. was included.

The comparisons are of interest and support the claim that the work of selecting for black root resistance is extremely promising. All the selections for black root resistance are, as an average of the three tests, better in sugar per acre than U. S. 216 x 226 Com'l. The selections made in 1947 or 1948, "Accessions," are as a class significantly below the "50-varieties," indicating definite improvement by an additional year of selection. The "50-varieties" are nearly all significantly better than "Local" in all tests.

In connection with tests of other years, it was reported that the selections for black root resistance have high quality. This is true also in 1951, as indicated by the sucrose percentages. As a group, the varieties show marked superiority in acre-yield of roots in comparisons with non-resistant sorts whenever black root is a factor.

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[3] Investigations on black root resistance are conducted in cooperation with the Michigan and Minnesota Agricultural Experiment Stations and in cooperation with the Farmers and Manufacturers Beet Sugar Association.

Results of Field Tests with Triploid Sugar Beets in 1951

DEWEY STEWART AND J. O. GASKILL[1]

Triploidy has been indicated as the chromosome complement giving the most vigorous growth in the sugar beet. The Swedish sugar beet breeders at Hilleshog, under the direction of Dr. J. Rasmusson, have found triploidy a promising method of producing improved varieties.

Autotetraploids of two leaf spot-resistant lines, U. S. 215 and U. S. 216, were established by Dr. F. A. Abegg by colchicine treatment. Results of field tests with these and other autotetraploid varieties were given at the 1946 meeting of this Society (1)[2]. It was concluded that the autotetraploids were generally slow in maturity and low in sucrose percentage but the acre-yield of roots and gross sugar was not significantly below that found in comparable diploid lines.

The autotetraploids of U. S. 215 and U. S. 216 have been hybridized with unrelated diploid lines, producing triploid sugar beets. In each of the matings to be reported, it has been possible to identify the triploid by color of the hypocotyl of the seedlings or by bud color in the larger plants. Stands of identified 3 *n* plants were left at thinning time insofar as possible. Ploidy was disregarded at harvest except that the percentage of triploid plants in each plot was recorded.

A productive inbred, Line U, which has shown excellent combining ability when crossed with the two U. S. varieties on the diploid level, has been mated with the two tetraploids. A comparison of the two triploid hybrids as given in Table 1 indicates a significantly greater acre-yield of of roots and gross sugar for U. S. 215 (4*n*) than for U. S. 216 (4*n*), as a pollen parent with Line "N." These differences in yield are considerably greater than reasonably could be expected as a result of the difference of 10 in percentage of identifiable triploid plants in the harvested population.

It can be stated from field tests, conducted in other years, with hybrids produced from the same combinations of these inbreds on the diploid level, that a higher productivity was obtained when U. S. 215 was mated with Line U just as found for the triploid. That is, triploidy as such has not changed apparently the relative breeding value of U. S. 215 and U. S. 216 as parents in combination with Line "U."

The triploid obtained by mating U. S. 216 MS, (2*n*) and U. S. 215 (4*n*) was not significantly unlike the commercial U. S. 215 x U. S. 216/3 (diploid) in any of the attributes evaluated.

The highest acre-yield of roots and gross sugar given in this report was shown by Line "U" (2*n*) x U. S. 215 (4*n*), but this triploid was not significantly unlike the diploid F_1 obtained from the mating of Line U and the male sterile phase of U. S. 225.

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[1] Senior Agronomist and Pathologist, respectively, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture.

[2] Numbers in parentheses refer to literature cited.

Table 1.—Comparison of Triploids and Related Diploids with Respect to Acre-Yield of Gross Sugar and Roots and also with Respect to Sucrose Percentage.

Parentage	Ploidy	Acre-Yield		Sucrose	Triploids[1]
		Gross Sugar	Roots		
		Tons	Tons	%	%
Line U (*rr*) x U. S. 216 (4*n*)	Triploid	3.264	18.61	17.51	68
Line U (*rr*) x U. S. 215 (4*n*)	Triploid	3.864	22.42	17.21	78
U. S. 216 (*rr*) MS x U. S. 215 (4*n*)	Triploid	3.683	21.58	17.03	100
U. S. 215 x 216/3 Com'l	Diploid	3.531	21.11	16.72	.....
U. S. 225 MS x Line U	Diploid	3.761	21.15	17.28	.....
Diff. Req. for Sig. (odds 19:1)		0.285	1.52	0.45	

[1] In harvested population, Triploids identified by bud color.

Attention should be directed to the sucrose percentage of the triploid hybrids. It has been indicated (1) that the tetraploids were generally low in sucrose percentage but these triploids compare favorably with the diploids. Two of the triploid hybrids are significantly higher in sucrose percentage than the commercial U. S. 215 x 216/3.

There is little in this preliminary report to permit one to evaluate triploidy as a means to new levels of productivity in the sugar beet since the hybrids under test did not afford the most critical comparisons. The two autotetraploids used as a parent in triploid hybrid production gave unlike combining ability in matings with Line U, which is in accord with their performance as diploids. Thus, to obtain productive triploids, it appears that autotetraploids are required as parents which have been obtained from diploids having good combining ability. Triploidy adds another step in the evaluation of inbreds as parental lines in the production of hybrid sugar beets and this new approach to varietal improvement is worthy of further investigation.

Conclusion

The results of a field test with three triploid sugar beet hybrids indicated equivalent productivity in acre-yield of roots and gross sugar to that of hybrids which can be produced from matings of related lines on the diploid level.

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Population and Distribution of Sugar Beets and Table Beets as Related to Seed Production[1]

RAY A. PENDLETON[2]

Introduction

Climatic conditions in western Oregon are particularly favorable for seed production of both sugar beets and table beets. In view of these favorable conditions some detailed studies have been made of the space relations for sugar beets where grown by the overwintering method and some preliminary studies made with respect to table beets transplanted for seed.

In some previously reported work (1)[3] it was found that with plantings made Sept. 3, about one-third of the plants in the unthinned stand failed to bolt, although in the thinned stand all plants bolted satisfactorily. In this trial slightly better seed yields were obtained from the thinned stand. In a dry land planting in 1943 with 24-inch rows, a continuous stand made 25 percent more yield than hills spaced on 24-inch centers. A trial in southern Oregon in 1947 involved irrigated beets with 20-inch rows. Spacings within the row varied from 1 to 8 plants per foot. In this test no difference in seed yield due to the spacing variables was obtained.

Other evidence demonstrates that time of planitng is an important factor. Sugar beets planted in early August or even more so in June or July gave more uniform and complete reproduction than those planted in September. However, in early plantings winter injury may be a hazard. Where spacing permits large individual root development in early plantings, the larger plants will suffer more from freezing than smaller plants in more crowded conditions.

No doubt many other factors will influence sugar beet seed yields. The question of optimum spacing will need exploring with several varieties and under different growing conditions before generalizations can be made.

Table beets for seed in this area are grown mainly by the transplanting method. Roots are grown in the summer and fall, then dug and placed in storage either in controlled temperature warehouses or in field pits during the winter and then transplanted in early spring. Relatively few are grown by the field-overwintering method. Usually the rows for the seed crop are spaced at three to four feet apart with roots 18 to 24 inches in the row. Operators have difficulty placing the plants closer than about 18 inches with present transplanting equipment. Some new developments in transplanting machines may change this situation.

Experimental Methods

In the 1949-50 season a study was made at Corvallis to test the effect

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[2] Agronomist, Div. of Sugar Plant Investigations, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, USDA.

[3] Numbers in parentheses refer to literature cited.

of spacing sugar beets both as to within-row variations and between-row variations. In a split plot, randomized block arrangement beets were planted in rows 12, 16, 20 and 24 inches apart. Spacings within the rows were 1. six-inch singles, 2. three-inch singles, and 3. unthinned which averaged about one plant per 1½ inches. This provided five replicates of the row-width blocks and 15 replicates of the within-row spacings for a total of 60 plots. For convenience of planting, cultivating and harvesting, it was desirable to vary the width of the plots so as to provide a definite number of rows. The 12 and 16-inch rows were planted to 12-row plots and the 20 and 24-inch rows to 9-row plots, all 90 feet long. The soil was a Chehalis sandy loam fertilized with a mixture of ammonium sulfate and sodium nitrate to supply a total of 300 pounds of N per acre, 100 in the fall and 200 in the spring. They were well irrigated. Beets were planted Aug. 3, 1949.

In the trial reported here with table beets for seed, the row width was limited to 3.5 feet. Within-row spacings were 8, 12, 24 and 48 inches. Plots were single rows 50 feet long with two levels of nitrogen and four replications of each. N1 nitrogen level was fertilized with ammonium nitrate to supply 60 pounds of nitrogen per acre. N2 nitrogen level had, in addition to that of N1, 60 pounds of N in the form of a mixture of ammonium sulfate and sodium nitrate. Only one irrigation was applied and the beets suffered from shortage of water. The soil was Chehalis silt loam.

Sugar Beet Seed Production

Fall growth was good and only a few of the single plants in the wider row spacings were killed by winter freezing. The seed was harvested the latter part of July, 1950, and the yields of clean seed calculated to an acre basis are given in Table 1.

Table 1.—Effect of Spacing on Sugar Beet Seed Yield in Pounds of Clean Seed Per Acre.

	Within-row spacings			
Row width	**6 inches**	**3 inches**	**Unthinned**	**Mean**
24 inches	3,895	3,718	3,923	3,845
20 inches	3,558	3,706	3,483	3,582
16 inches	3,885	3,889	3,896	3,889
12 inches	3,852	3,695	3,543	3,697
Mean	3,798	3,752	3,711	

Treatment differences all non-significant at 5% level.

Within the range of the plant population, which varied from about 47,000 per acre to about 238,000, there was no difference in seed yields under the conditions prevailing. In these relatively early fall planted beets the smaller individual plants of the thick stand had sufficient opportunity for induction of flowering that nearly all made seed.

Beet seed growers in this area have decided from their own observations that it is preferable to obtain moderately thick stands. There may be some advantage to this. For one thing, there may be considerable less hazard of winter injury in thick stands. Another point is that the weeding problem is somewhat less with relatively thick stands. In a previous study of the relative amount of hand labor for weeding, it was found that beets

spaced as 12-inch singles required five times as much labor for weeding as an unthinned stand and beets spaced as 6-inch singles required twice the labor of unthinned stands. These were in 20-inch rows.

Sugar Beet Seed Quality

The germination test of these samples was all good, averaging 93 percent with no significant difference due to the spacing treatments. There was a significant trend toward smaller sized seed from the closer spaced plants. The average weight per 100 seed balls is given in Table 2.

Differences in seed ball size of the magnitude shown in Table 2 would not be clearly defined in a screening test. Sugar beet seed passing through a 12/64ths screen and held on an 11/64ths average about 2.04 grams per 100 seed balls. Seed 1/64th larger size averaged 2.50 grams and seed 1/64th smaller averaged 1.70 grams per 100 seed balls. Different seed lots might vary due to the severity of rubbing during threshing operations. In this seed lot, the germ portion averaged 22.4 percent of the total seed ball weight.

Table 2.—Effect of Spacing on Seed Ball Weight in Grams Per 100[1].

	Spacings within-rows			
Row width	**6 inches**	**3 inches**	**Unthinned**	**Mean**
24 inches	2.24	2.18	2.26	2.22
20 inches	2.08	2.26	2.00	2.12
16 inches	2.16	2.16	1.96	2.10
12 inches	2.02	2.12	1.92	2.02
Mean	2.12	2.18	2.02	

Difference for significance of row width means at 5% level—.134.
Difference for significance of within-row means at 5% level—.116
[1] For convenience in conversion 2.00 grams per 100 seed balls is equivalent to 22,680 seed balls per pound.

Remaining Plant Population at Harvest

The spacings and plant population as reported above refer to the stand remaining after thinning in the fall. The significant stand would be that remaining at harvest time. Where the plants were thinned to six-inch singles and rows 24 inches apart, some winter freezing loss occurred and only about 80 percent of the original stand remained. In the other row widths the thinned stands showed good survival and at harvest survival was essentially the same as at thinning time. On the other end of the scale the unthinned stand resulted in some crowding in the 12-inch rows with a subsequent loss of about 30 percent of the plants, leaving 5.5 per foot of row; similarly, there was a lesser loss from crowding in the 16-inch row, leaving 6.8 per foot in this unthinned stand. The 20- and 24-inch rows showed good survival where they were not thinned, with the stand about as at thinning time wtih eight plants per foot.

From the standpoint of number of plants per square foot of land area, the counts showed 5.5, 5.1, 4.8 and 4.0 respectively for the 12, 16, 20 and 24 rows unthinned and down to only 1.09 average per sq. foot for the thinned stand in 24 inch rows. Over a range of five-fold difference in total plant population remaining at harvest, there was no measurable difference in seed production.

Table 3.—Effect of Spacing on Root Weight in Tons Per Acre.

Row width	Within-row spacings			
	6 inches	3 inches	Unthinned	Mean
24 inches	7.40	7.23	6.58	7.07
20 inches	7.80	8.10	8.49	8.13
16 inches	9.24	8.23	8.40	8.62
12 inches	10.93	9.15	8.36	9.48
Mean	8.84	8.18	7.96	

Size of Roots

Where sugar beet seed is being grown by the overwintering method and the byproduct of roots is not used after seed production, the size of roots produce is of only secondary importance. However, it seemed desirable to take sufficient samples of roots from these spacing plots to get a fair estimate of the total root production. Root weights of representative samples of the plots were taken at harvest time and are shown in Table 3.

In this trial the variance in tonnage of roots produced was not large. The spread between the greatest and least population amounted to only about one ton per acre.

Table Beet Seed Production

Yields of table beet seed calculated to pounds per acre are given in Table 4.

Table 4.—Table Beet Seed Yields as Pounds Clean Seed Per Acre.

Nitrogen Level	Spacings with rows				
	8 inches	12 inches	24 inches	48 inches	Mean
N1	2,365	2,589	1,742	1,556	2,056
N2	2,489	2,116	1,718	1,182	1,874
Mean	2,427	2,350	1,730	1,369	

Diff. for significance of spacing at 5% level—336 pounds.

As shown in Table 4 seed yields from the 8 or 12-inch spacing were about equal, averaging 38 percent better than the 24-inch rows and 75 percent better than the 48-inch rows. Under the conditions of moisture deficiency, the added nitrogen was of no benefit. Spacing had no effect on the seed size.

There was some mortality and the stand at harvest time averaged about 80 percent for the 8-inch, 75 percent for the 12-inch, 85 percent for the 24-inch and 92 percent for the 48-inch spacings. Harvest weight of roots per acre was somewhat in proportion to the seed weights. The 8-inch spacing produced about 6,500 pounds roots, the 12-inch produced about 5,400 pounds, the 24-inch produced about 3,900 pounds, and the 48-inch produced about 2,800 pounds or average weights per beet root ranging from .110 for the 8-inch to .246 for the 48-inch spacing.

Summary

The relation of spacing and total plant population of sugar beets to seed yields was investigated. Row widths were varied at 12, 16, 20 and 24

inches, and spacings within the row were varied at 1. 6-inch singles, 2. 3-inch singles, and 3. unthinned, which averaged about one every 1½ inches.

Under the conditions prevailing in this experiment, with seed yields ranging from 3,600 to 3,900 pounds per acre, there was no difference in seed yields attributable to the spacing treatments.

The closer spacing resulted in slightly smaller seed but did not affect germination.

Total weight of roots produced ranged from 6.6 tons per acre for the unthinned plants in 24-inch rows to 11 tons per acre for the 6-inch singles in 12-inch rows.

The effect of spacings for transplanted table beets for seed was tested in a row width of 3.5 feet and spacings within the row of 8, 12, 24 and 48 inches. The seed yields were about equal from the 8- and 12-inch spacings and were 75 percent higher than the 48-inch and 37 percent better than the 24-inch spacings. Neither size nor germination of the table beet seed was affected by the spacings.

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The Dispersion of Pollen in Sugar Beet Seed Plots

DEWEY STEWART[1] AND SAM C. CAMPBELL[2]

Introduction

Cytoplasmic male sterility (6)[3] as a tool in sugar beet breeding facilitates the production of hybrid seed. If a completely male sterile equivalent of an inbred is used in the production of F_1 seed, a companion line with which it combines well should be used as the pollinator. Pollen dispersal within seed plots, always important in sugar beet breeding to maintain heterozygosity, becomes a necessity if seed set is to be obtained on the pollen-sterile plants. If only F_1 seed will be acceptable, then the land area planted to the pollinator will tend to reduce the acre yield of marketable seed and in other ways increase the cost of production (2). If this method of seed production should come into use it is therefore highly important to know the proper ratio and distribution of the pollinator with respect to a male-sterile parent which will assure pollination of all the pollen-sterile flowers without unduly adding to seed cost.

Anticipating the availability of completely male sterile equivalents of leaf spot-resistant inbreds for production of hybrid sugar beet seed, plantings were made in the fall of 1950 at the Plant Industry Station, Beltsville, Maryland, and near Medford, Oregon,[4] for the purpose of making a study of pollen dispersal from a pollinator.

Materials and Methods

A partially male sterile equivalent of U. S. 216, a second backcross designated as SP 47100-01, was used as the mother parent. When grown at the Plant Industry Station approximately 60 percent of the plants of this inbred produced flowers with shrunken white anthers devoid of pollen. Of the remaining plants, 15 to 25 percent produced flowers with plump yellow anthers which approached normal pollen production. However, plants in this latter category were not readily separated from intermediate types which comprised the remainder of the population.

Five hundred plants in each of the three plots in Oregon were classified as to anther type. The white anther class comprised 42.6 percent, 45.0 percent and 52.2 percent in Plots 1, 2 and 3 respectively. The yellow plump anther class for these plots given in the same order was 35.0 percent, 32.0 percent and 32.4 percent. These percentages may indicate variations between locations as to anther types or may merely be indicative of the difficulty experienced in establishing sharply defined classes. SP 47100-01 is the recessive genotype *rr*, for the factors determining color in the hypocotyl, buds and other parts of the plant.

A strain of U. S. 215, SP 461001-0, was used as the pollinator in this study. It is vigorous, produces pollen in abundance and its date of flowering is fairly close to that of SP 47100-01. SP 461001-0 is homozygous dominant with respect to the *R* gene.

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[2] Manager, West Coast Beet Seed Co., Salem, Oregon.

[3] Numbers in parentheses refer to literature cited.

[4] The plots in Oregon were provided through the cooperation of the Farmers and Manufacturers Beet Sugar Association, Saginaw, Michigan.

The plots were approximately 1/8 acre each with rows 40 to 50 feet in length. All rows were four feet apart except for Plot 3 in which the rows were two feet apart. The seeding rate was comparable to that used in commercial seed fields and the seedling stands were not thinned. In Plots 1 and 2 in Oregon and in Plot SF-4 at Plant Industry Station, the strip of the pollinator, SP 461001-0, was in the center of the field and on each side there were 12 rows of the partially male sterile strain, SP 47100-01. Oregon Plot 1 had a four-row strip of the pollinator; Plot 2 and SF-4 each had only a single row. Plot SG-12A at the Plant Industry Station had a four-row strip of the pollinator but it was not centrally located. In Oregon Plot 3, there were three four-row strips of the pollinator, one in the center and the other two as the outside four rows of the field. Between the central strip of the pollinator and the two outside ones there were 16 rows of SP 47100-01.

During the height of the blooming period approximately 20 white anther plants and 20 pollen-fertile plants of each row of SP 47100-01 were tagged for a separate harvest by anther types. The yield of seed for these 20-plant samples ranged from one to two pounds. After threshing and cleaning, each lot of seed was run repeatedly through a Boerner sampler to obtain a one-ounce sample for analysis. Each small sample was taken as the representative of its row and was used to obtain the results to be presented. Two hundred seedballs from each sample were planted in sterilized sand in a manner permitting the percent of germination of seedballs, the number of sprouts as well as the ratio of hypocotyl colors, pink to green in the seedling populations, to be determined. From each planting of 200 seedballs a population of approximately 380 seedlings was obtained.

Results

The F_1 from the mating, 47100-01 *rr* x 461001-0 *RR* can be identified in the seedling populations by pink hypocotyl color. It should be noted that pollen fertile plants of SP 47100-01 produced *r* pollen and the extent to which this pollen was effective in bringing about selfing as well as fertilizations in siblings will be indicated by the recessive phenotype, or green hypocotyl color. Since the F_1 in the reciprocal cross could not be identified the seed from the pollinator was of no interest.

White Anther and Pollen-Fertile Phases

In a stand of sugar beets producing a variety of anther types with respect to pollen sterility as indicated for SP 47100-01, the highest percentage of F_1 seedlings was expected in the progeny of the white anther plants after exposure to unrelated pollen. That is, any tendency for self-fertilization in flowers of the pollen-fertile plants would tend to reduce the percentage of hybridizations while in the white anther siblings only out-pollination could occur.

In Figure 1 the percentage of F_1 seedlings in the progeny of pollen-fertile and of white anther phases have been indicated for each row of SP 47100-01 in Plot SF-4. The respective anther types of the rows gave strikingly similar values for the percentage of hybridization at each four-foot interval from the pollinator. The mean percentages of F_1 seedlings for the west side of the pollinator were 18.9 percent and 17.1 percent for the

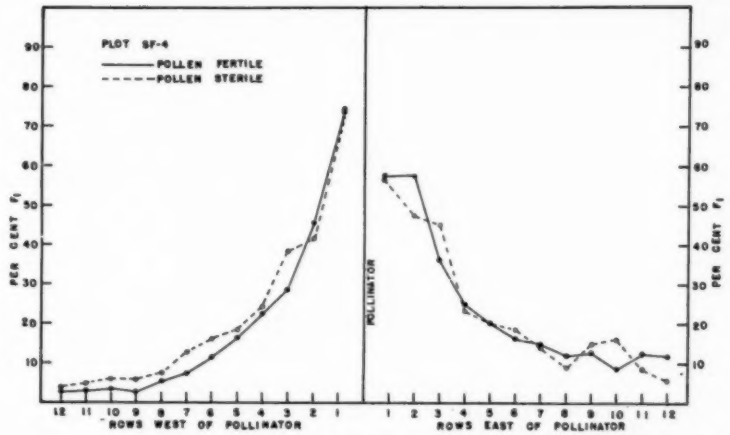

Figure 1.—The percentage of F_1 seedlings in the pollen-fertile and pollen-sterile phases of SP 47100-01 are shown for each row of Plot SF-4. The rows were four feet apart. There was a single row of the pollinator, SP 461001-0.

white anther and pollen-fertile phases respectively. On the east side the values given in the same order for anther types were 21.4 percent and 22.2 percent.

The tendency for the progenies of the white anther and pollen-fertile phases to give similar ratios of hybrids to non-hybrids was found also in the three Oregon plots. The mean F_1 value for all rows of Plot 1 was 24.5 percent for the white anther plants and 27.9 percent for the pollen-fertile phase. The other two plots gave a slightly higher percentage for the white anther plants than for the pollen-fertile ones. Results from 103 rows of S.P. 47100-01 in SF-4 and Oregon Plots 1, 2 and 3 which had been sampled in a similar manner were critically compared with respect to numbers of F_1 seedlings in progenies of the white anther and pollen-fertile phases. The percentages of hybrids in a balanced comparison of anther types were 38.34 percent and 37.80 percent respectively. The difference of 0.54 percent was not statistically significant as determined by *t*-test applied to differences in paired row samples. Since the pollen-fertile plants of S.P. 47100-01 did not differ significantly from the white anther phase with respect to the percentage F_1 when exposed to a mixture of pollen from related and unrelated plants, the results of the two samples from each row have been combined for the remainder of the presentation.

Regions and Pollen Dispersion

Plot SF-4 at the Plant Industry Station was similar to Plot 2 in Oregon both in size and number of rows. Each had a single row strip of the pollinator located in the center of the plot. The percentages of F_1 seedlings for rows west and east of the pollinator in these plots have been indicated in Figure 2. The mean percentages of hybrid for Plot 2 in Oregon were 17.6 and 35.6 for the rows west and east respectively of the pollinator. For

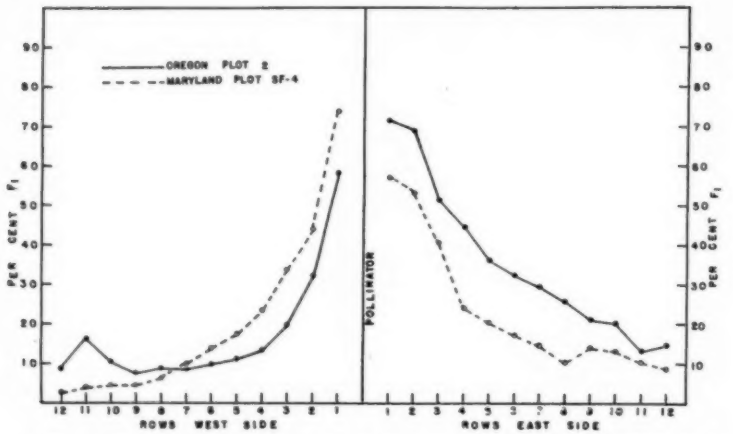

Figure 2.—Percentage F_1 seedings in row progenies of SP 47100-01 in Oregon Plot 2 and Maryland Plot SF-4. In each plot there was a single row of the pollinator, SP 461001-0. The rows were four feet apart.

Plot SF-4 in Maryland the values were 20.2 percent and 24.5 percent for the west and east sides respectively. The average lower percentage for the Maryland plot is attributed to a dike and trees on the west side which provided a windbreak, rather than to regional differences.

There was a tendency for the hybridizations to be higher on the east side of the pollinator than on the west in both plots but the tendency was most striking in Plot 2 where the mean percentage of F_1 for the 12 rows on the east side was double that for the same number of rows on the west side. This tendency for a unilateral movement of pollen is an indication of the prevailing direction of air currents over the plots and is further evidence that insects are a minor factor in the pollination of sugar beets (7).

Width of Pollinator Strip

Plot 1 had a four-row strip of the pollinator and Plot 2 had only a single row strip, otherwise they were identical in design. The ratios of F_1 seedlings in the progenies of comparable rows in these plots may be used to indicate the relative efficiency in pollination of four-row and one-row strips. The percentages for the rows of Plots 1 and 2 have been shown in Figure 3. It should be noted that the rows north of the pollinator in Plot 1 have been shown in comparison with those of the west side of Plot 2. These are the windward sides and presentation in this manner aids in making comparisons. The rows on the south and east sides of the plots are similarly contrasted.

Except for a slightly higher ratio of hybrid seedlings for the rows immediately adjacent to the four-row pollinator in Plot 1, the percentages were surprisingly similar in comparable rows of these two Oregon plots. The rows north of the four-rows of pollinator in Plot 1 and those west of the one-row pollinator in Plot 2 gave a mean F_1 of 16.6 percent and

17.6 percent respectively. The rows on the south side and east side of the pollinator in these plots, given in the same order, were 35.1 percent and 35.6 percent. The mean percentage in all rows of SP 47100-01 in Plot 1 was 26.2 percent and in Plot 2 was 26.8 percent.

The incidence of pollen for a given distance from a point of release should be a function of the amount liberated. If one assumes that the ratios of the fertilizations produced by *R* and *r* pollen are directly related to their concentration in the air, then one would expect a higher percentage of hybridization from a four-row than from a single-row strip of the pollinator. The failure of Plot 1 with a four-row strip of the pollinator to show a general increase in effective *R* pollen over Plot 2 with a single row cannot be attributed to a sparse stand. Stand estimates were made and rows of the pollinator in Plot 1 were not noticeably deficient in plants. Furthermore, a comparison of seed yields for the pollinator in the two plots through the performance of the adjacent rows of SP 47100-01 indicated comparable stands. A partial explanation of the failure to get increased hybridization with the four-row strip of the pollinator should be

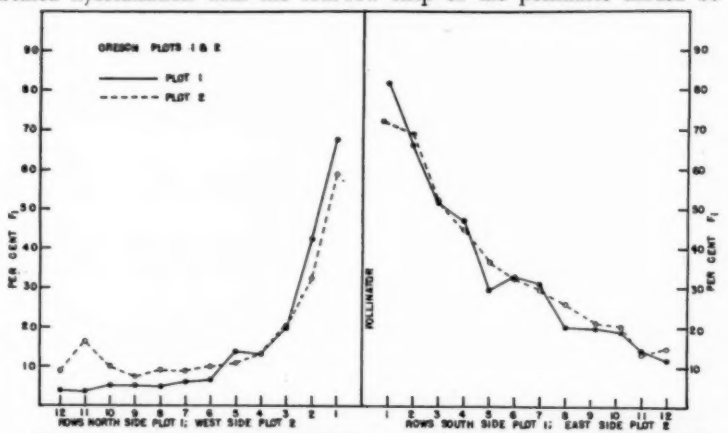
OREGON PLOTS 1 & 2
PLOT 1
PLOT 2
PER CENT F1
POLLINATOR
ROWS NORTH SIDE PLOT 1; WEST SIDE PLOT 2
ROWS SOUTH SIDE PLOT 1; EAST SIDE PLOT 2

Figure 3.—Percentage F_1 seedlings in row progenies of SP 47100-01 in Oregon Plots 1 and 2. In Plot 1 there was a four-row strip of the pollinator SP 461001-0; in Plot 2 a single row, otherwise the plots were identical in design.

sought in the 12-row strips of the recipient. Rows progressively farther from the pollinator showed a marked reduction in the percentage of F_1 seedlings. In a 12-row strip of a pollinator, it is evident that the innermost rows would contribute pollen mostly to companion rows and relatively little to a recipient variety in an adjoining area. However, one would expect the center rows of the four-row pollinator to increase the total hybridization a greater distance than one or two rows as indicated in Figure 3. If it could be established through additional tests that a single row of the pollinator is essentially as effective as a strip four rows wide or wider in bringing about fertilizations in adjoining area of a recipient variety, this information could lead to important savings in the cost of F_1 seed.

Dispersion of Pollen As a Function of Distance

The percentage germination, seedlings per seedball, and percentage of F_1 seedlings for rows of SP 47100-01 in Plot SF 4, and the combined values for Oregon Plots 1 and 2 are given in Table 1. In this summarization the values of the white anther and pollen-fertile phases have been combined for each row as well as the corresponding rows on each side of the pollinator.

Table 1.—Results Given as Means for Percentage Germination, for Seedlings Per Seedball, and Percentage F_1 from Companion Rows of SP 47100-01 in Plot SF-4 Plant Industry Station, Beltsville, Maryland, and in Plots 1 and 2 Near Medford, Oregon.

	Plot SF-4			Plots 1 and 2		
Row[1]	Germination[2]	Seedlings per Seedball[3]	F_1 Seedlings[4]	Germination[2]	Seedlings per Seedball[3]	F_1 Seedlings[4]
	%	Seedlings	%	%	Seedings	%
1	90.3	1.97	65.5	90.3	1.94	69.5
2	89.1	1.88	48.3	91.1	1.91	52.3
3	89.3	1.93	37.0	91.1	1.89	36.3
4	91.5	1.90	23.7	91.8	1.95	30.3
5	87.1	1.80	19.0	89.7	1.91	23.0
6	91.6	1.88	15.7	90.9	1.88	21.3
7	93.1	1.84	12.2	93.7	1.94	19.2
8	89.9	1.79	8.4	93.8	2.00	15.1
9	89.1	1.89	8.8	92.2	1.92	14.0
10	89.0	1.82	8.5	93.4	1.90	13.7
11	87.0	1.77	6.9	89.9	1.87	12.1
12	89.0	1.83	5.8	90.1	1.80	10.0
Mean	89.7	1.86	21.7	91.5	1.91	26.4

[1] Each of the rows four feet from the centrally located strip of the pollinator is designated Row 1. Rows progressively farther from the pollinator are indicated by increasingly larger consecutive numbers.
[2] One seedling per seedball indicated germination. Values given as means of 800 seedballs, 400 from the pollen-fertile plants and 400 from the white anther phase of SP 47100-01.
[3] Values calculated from the total seedlings obtained from the seedballs germinating.
[4] F_1 seedlings were identified by hypocotyl color.

It has been assumed that the production of *r* pollen was uniform over the plantings of SP 47100-01. If the effectiveness of *R* pollen in the mixture is not changed with dilution, then the percentage of F_1 seedlings in the row progenies can be taken as indicating its relative concentration over the rows which were located at four-foot intervals from the pollinator. The percentages of hybrid seedlings occurring on each side of the three plots were plotted on semi-logarithmic paper as a series of associations. The values for the south side of Plot 1 and the east side of Plot 2 gave a fair fit to a straight line for all rows but in the other plots the rows farthest from the pollinator showed wide deviations. This indicated for the three plots in general an exponential relationship for the rate of decrease of *R* pollen concentration and distance. In a generalized manner this relationship is given by the curvilinear regression line in Figure 4. The percentages for SF-4 and Oregon Plots 1 and 2 as given in Table 1 have been averaged for the calculations. The F_1 percentages computed from the regression equation Log. $Y = 1.83917 - .07715X$ and the averages of the observed values are significantly correlated, *r* being equal to 0.97. For each row interval of four feet from the strip of the pollinator the logarithm of the percentage F_1 which is interpreted as the relative concentration of *R* pollen is reduced uniformly by 0.07715.

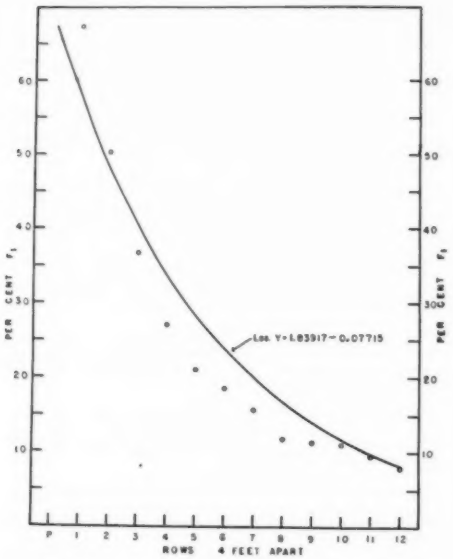

Figure 4.—Curvilinear regression line showing relation of row interval of four feet and percentage of F_1 seedlings. The average F_1 percentages for SF-4 and Oregon Plots 1 and 2 as given in Table 1 were used in the calculations. The average values from the table are indicated by small circles.

If X is taken as 24 in the above regression equation the estimated percentage F_1 at 96 feet from the pollinator would be 0.97 percent. It is interesting to note there was a fair confirmation of this estimation in Plot SG-12A on the Plant Industry Station. In this plot the row width and varieties were the same as before but the four-row strip of the pollinator was not centrally located. There were 50 rows of the recipient variety east of the pollinator. The first row, four feet from the pollinator, gave 69.8 percent F_1 seedlings, which is comparable to values for similar locations in the other plots. The twenty-fourth row east of the pollinator gave only 0.6 percent hybrid seedlings, which conforms reasonably well with 0.97 percent computed from the regression equation. The ratio of hybrid to non-hybrid seedlings in the row progenies of Plot SG-12A gave further agreement with those obtained by the extrapolation of the regression line shown in Figure 4. For the portion of the field ranging from 100 to 200 feet east of the pollinator none of the seed samples gave more than 2.9 percent hybrids in the populations grown and the mean F_1 for the 26 rows was 0.7 percent. Although not in accord with the regression equation but to an extent expected due to sampling error, ten of the 26 rows in the 100 to 200-foot sector of the field gave no F_1 seedlings.

The percentage germination and the seedlings per seedball as given

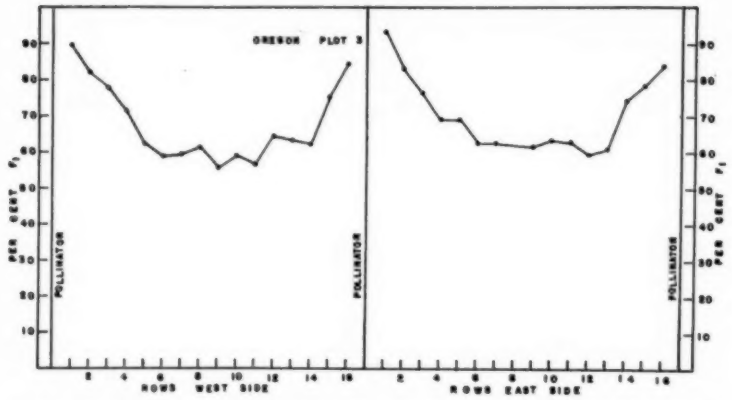

Figure 5.—The percentage of F_1 seedlings in row progenies of SP 47100-01 in Oregon Plot 3. There were alternating strips of the pollinator (four rows) and the recipient variety (16 rows). The rows were two feet apart.

in Table 1 do not show a significant change for the rows progressively farther from the pollinator, which is in accord with the report by Campbell (2). The quality of the seed harvested from rows farthest removed from the pollinator indicates that the pollen-fertile plants in SP 47100-01, judged to be 15 to 30 percent of the population, produced effective pollen in ample quantities to bring about the usual extent of fertilization obtained in commercial seed crops.

Alternating Strips of Pollinator and Recipient

Alternating strips of the pollinator and SP 47100-01 were used in Oregon Plot 3. The strips of the pollinator were four rows wide and those of the recipient 16, giving an arrangement of 4-16-4-16-4 for the plot. The results are presented in graph form in Figure 5.

It should be noted that the rows in Plot 3 are two feet apart instead of four as in the plots discussed previously. The influence of distance on percentage hybridization is strikingly demonstrated in Figure 5. Row 1 of the west strip of SP 47100-01, and row 1 of the east strip, occurring on the leeward side and two feet from a strip of the pollinator, gave for F_1 seedlings 89.9 percent and 93.1 percent, respectively. Row 16 of the west and of the east strip, which might be considered as occupying the windward side of the pollinator, gave 84.1 percent and 84.3 percent respectively. These values show increased hybridization in the two-foot rows over the four-foot width used in SF-4 and Plots 1 and 2. The percentage values for the windward and leeward side of the pollinator indicate a strong unilateral distribution of pollen in the plot from west to east, which is attributed to wind transport.

It is evident that a 16-row strip (32 feet) of SP 47100-01 is too wide to give a high F_1 percentage in the seed crop. The percentages tend to level off at approximately 60 percent for the eight or nine centrally located rows but this is a marked reduction from the high percentages given for

the rows adjacent to the pollinator. Judging from the values for the second row from the pollinator, it is estimated that 80 percent or more F_1 seed would have been obtained from a four-row strip of SP 47100-01. Likewise, the values for the rows adjacent to the pollinator indicate that alternate single row planting might have given 90 percent F_1 seed for the recipient in this plot.

Discussion

No attempt has been made to determine the amount of *R* pollen produced by the pollinator or the amount of *r* pollen produced by SP 47100-01, but it is assumed that the latter type was produced uniformly over the strips of this variety. The percentage of F_1 seedlings in the row progenies should give the relative ratio of the two pollen types for the various parts of the field. That is, a reduction in the percentage of hybrid seedlings in the progenies of row progressively farther from the pollinator is taken to indicate a relative dilution of *R* pollen in the pollen mixture which reaches a given plant.

The data which have been presented indicate clearly that most of the pollen liberated by the pollinator and settling in the plots came to rest only a short distance from the point of release. This is illustrated by the regression line in Figure 4. If the equation $\text{Log. } Y = 1.83917 - 0.07715X$ is given in the exponential form then the estimated percent $F_1 = (69.05)(.8372)^X$. Thus, according to this equation the concentration of effective *R* pollen over a row as an average was 83.72 percent of that over the adjacent row nearer to the pollinator, or a reduction of 16.28 percent for the four-foot interval.

It should be recognized that the settling out of the initial quantity of *R* pollen in the plots is not the major factor in bringing about a reduction in its concentration except possibly for clumps of pollen which would tend to settle rapidly on the rows nearest the pollinator. Basically, the reduction in pollen concentration with distance is due to its dispersion brought about by turbulence and gustiness of the air in a manner similar to the spread of smoke over and across a landscape from a campfire. That the rate of dispersion as well as the distribution pattern of pollen from a point of release is greatly influenced by the vagaries of the wind has been demonstrated by Colwell (3).

Although the hybridizations occurring in Plot SG-12A showed a general concordance with percentage of F_1 seedlings computed from the regression equation giving average values for three other plots, the real significance of the equation is to show the logarithmic rate of reduction with units of distance rather than to establish specific values. It is reasonable to assume that the dispersion of *R* pollen would be expressed by a reduction in hybridization and a concomitant increase in fertilizations by *r* pollen. The nonlinear relationship found in this study for pollen dilution with distance from a pollinator is in accord with the reports in literature concerning the dispersion of pollen, fungous spores and other particles polluting the air. (5).

The exponential equation focuses attention on distance as the major factor in maintaining high concentration of pollen over a recipient variety in the production of hybrid seed. In Plot 3, SP 47100-01 gave over 90 percent hybrid seed in a row two feet from the pollinator, which indicates the extent hybridization may occur. The minimum distance between plants of two lines to be hybridized could be obtained by the use of a seed mixture as planting stock. This method has been used in the commercial production of U. S. 215 x 216 (4) and other combinations of leaf spot-resistant inbreds. However, this scheme of producing hybrid seed requires a strong tendency for self sterility as well as relatively high productivity in the parental lines, otherwise the non-hybrid phase even though small may markedly reduce the yielding capacity of the variety. Hybrid varieties of sugar beets containing only F_1 seed can be produced if completely male-sterile equivallents of an inbred line are used as the seed bearer and supplied with a pollinator.

The concentration of pollen required in the air surrounding male sterile plants to give fertilization in all the flowers is not known. It should be mentioned that Owen (6) has reported high seed yields of a hybrid from alternating strips, four rows of the pollinator and 16 rows of 100 percent male-sterile plants obtained by clones. In the light of the results which have been presented, one would expect the egg nucleus in the sugar beet to remain receptive for a fairly long period, and with low pollen concentrations the chance of fertilization would become a function of the period of receptivity. This emphasizes the need for complete male sterility of all plants in the equivalent inbred used as the seed bearer, since an occasional fertile plant would produce proportionately more fertilizations under conditions of low total pollen concentration. For the same reason the problem of volunteers from previous seed crops looms large if cytoplasmic male-sterile plants are used in the production of commercial F_1 seed.

The exponential relationship of units of distance and the rate of reduction in F_1 production in a recipient variety by a pollinator has a bearing on the polycross method of breeding sugar beets. If the plants to be interpollinated occupy a large area, or if they are planted in rows of considerable length, the pollen mixture over the various hills of the plot would be strikingly unlike qualitatively. Therefore, a progeny test could not evaluate the relative combining ability of the plants comprising the polycross group, but more precisely it would indicate the combining ability of the seed bearer and a few nearby plants as the major source of pollen. A pollinator with a genetic marker as in this study if otherwise acceptable would be an aid in determining the relative breeding value of individuals in a group, since a specific hybrid combination would be identifiable.

This study of pollen dispersion within sugar beet seed plots does not indicate the extent to which pollen from the pollinator may be transported beyond the boundary of the field. However, from the literature, which has been reviewed by Archimowitch (1), it is known that sugar beet pollen may be wafted to great heights and transported over long distances.

Summary

The dispersion of pollen from a pollinator in sugar beet seed plots has been studied by means of identifiable hybrids in row progenies of a recipient

variety. In plots of similar size and design a four-row strip of the pollinator did not give appreciably higher percentages of hybridization than a single row. A slightly lower percentage of hybridization in a plot at the Plant Industry Station, Beltsville, Maryland, than in one near Medford, Oregon, with equal plantings of the pollinator was attributed to a local condition and not to a regional influence. There was a marked unilateral distribution of pollen within the plots from the pollinator, which was attributed to wind transport.

The percentage of hybrid seedlings in the row progenies of the recipient was reduced at a logarithmic rate with distance from the pollinator. The curvilinear regression based on averages of three plots indicated that the computed percentage of F_1 seedlings in a row progeny would be 83.72 percent of the adjacent row, four feet nearer to the pollinator.

The bearing of the results of this study on commercial hybrid seed production and on methods of sugar beet breeding has been discussed.

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Polyploid Sugar Beets—Cytological Study and Methods of Production

HELEN SAVITSKY[1]

Introduction

It is not quite clear at present whether or not polyploidy could be used to increase the productivity of sugar beets (1, 3, 5)[2]. However, triploids which show heterosis have been developed (2, 3). Polyploidy increases the size of fruits and germs. This property, which counts for little in multigerm beets, can prove very useful in monogerm beets (4). To gain the advantages of polyploidy, it is necessary to develop an easy method of obtaining a sufficient number of tetraploid plants. Such methods must be based upon treatment of the growing point in young seedlings, because the growing point can produce pure tetraploid floral axes. Treatment of the floral axes themselves may cause chimeras or merely islands of $4n$ tissue. Studies were made to determine the importance of 1. concentration of colchicine solution, 2. duration of treatment and 3. the age of seedlings when the treatment is most effective.

Material and Methods of Treatment

Seedlings of curly-top-resistant strains SL 824 and SL 92, both of which represent selections from the commercial variety U. S. 22/3, were used in the experiment. From both strains tetraploid plants were obtained. Young seedlings were taken from soil, washed and tied in bunches of 50 seedlings each. These bunches were plunged upside down in a crystallizing dish filled with colchicine solution. The cotyledons and the upper part of the hypocotyls were covered by the solution. The roots were wrapped together in wet cheesecloth. A reverse treatment was also carried out with bunches of roots placed in colchicine solution. The crystallizing dishes containing the seedlings were covered by glasses. The temperature during the treatment was maintained at 27° C. The seedlings were placed in a well-lighted room and supplementary light was used at night. Thus, the conditions for growth were optimum and the seedlings grew under the treatment. After treatment the seedlings were rinsed in water and transplanted into pots.

The concentrations of colchicine applied were: 0.05, 0.1, 0.3, 0.4, 0.5 and 1.0 percent. Duration of treatments was 7.5 hours, 16 hours and 24 hours. Seedlings of the same age transplanted without treatment were used as a control.

The number of plants which produced $2n$ instead of the normal n gametes showed the effectiveness of treatment in each experiment.

About 1,500 seedlings survived after treatment and in 897 of them the gamete formation was examined.

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[1] Collaborator, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture in cooperation with the Curly Top Resistance Breeding Committee.

[2] Numbers in parentheses refer to literature cited.

Experimental Results and Discussion

Effect of Duration of Treatment and Colchicine Concentration

After 7.5 hours of treatment, the number of seedlings which survived in pots outdoors in August was relatively high and was only a little less than the control (Table 1). The mortality of seedlings increased when 1.0 percent colchicine was applied or when the treatment was extended for 16 hours. The survival after 24 hours of treatment was very low, so the experiments were delayed until fall when the seedlings could be transplanted into the greenhouse. In the greenhouse the survival was considerably better. To obtain the highest possible number of well-rootd seedlings it was found necessary 1. to use healthy seedlings, unaffected by root rot, 2. to provide moderate temperatures after transplanting (15° to 25° C.), without sudden changes and with relatively high humidity. The appearance of the first, second and third leaves was slower in treated seedlings than in the control. This indicates a slower rate of growth. After 7.5 hours of treatment the slowest growth was observed with 1.0 percent colchicine. The rate of growth was especially slow after 16 and 24 hours of treatment. Seedlings rooted after treatment were feeble and started to develop leaves slowly. This was the most critical period in their lives. They recovered slowly but after development of the second and third pair of leaves they grew normally.

Table 1.—Effect of Duration of Treatment and Colchicine Concentration.

		Time of Treatment			
		7.5 hours		16 hours	24 hours
Percent colchicine	Untreated control	cotyledons treated	roots treated	cotyledons treated	cotyledons treated
	%	%	%	%	%
			Percent 4*n* plants		
0.05		5.0	----	----	5.2
0.1		5.7	4.2	16.1	9.0
0.3		10.5	5.1	4.1	7.6
0.4		5.6	----	----	----
0.5		16.6	9.7	6.6	11.2
1.0		0.0	4.1	18.1	10.5
			Percent survival		
0.05		81	----	----	96
0.1		82	----	83	99
0.3		77	----	21	86
0.4		62	----	----	----
0.5		83	----	58	86
1.0		45	----	6.0	60
Untreated control	89				

All treated seedlings were classified as affected or unaffected. Unaffected seedlings grew rapidly and did not develop thick leaves and hypocotyls. The number of unaffected plants was very insignificant when seedlings were treated by plunging in colchicine solution. Only when the low concentrations of colchicine (0.05 and 0.3 percent) were applied about 2 percent of the plants were unaffected. Under heavier concentrations or by longer treatment all seedlings showed thick hypocotyls, cotyledons and leaves, and they developed slowly. Some treated seedlings showed much depression,

they were dwarf with small, narrow, irregular leaves and developed extremely slowly. The number of dwarf plants increased with heavier concentrations of colchicine and after prolonged treatments.

Different concentrations of colchicine solution gave approximately the same percentage of tetraploid plants (Table 1). The best concentrations for seedling treatment are considered to be 0.3 to 0.5 percent because these concentrations do not damage the seedlings as much as the heavier concentrations and at the same time they are strong enough to produce tetraploids.

Duration of treatment beyond 7.5 hours was not important. The percentage of 4*n* plants varied considerably with treatments at different concentrations and sometimes lower concentrations were more effective than the higher concentrations. This indicates that some other factors besides colchicine concentration influenced the results.

Effect of Treatment on Seedlings of Different ages

Seedlings were treated by plunging the cotyledons and the upper part of the hypocotyls into 0.3 and 0.5 percent colchicine solution for 5.5 hours at the following stages of development:

1. When the first pair of leaves had scarcely appeared between the cotyledons. This group represented the oldest seedlings.
2. Before the first leaves appeared. (When one of the cotyledons is torn off a small swelling between cotyledons and two small transparent scales, rudiments of the first pair of leaves, may be seen with the aid of binoculars).
3. Still smaller seedlings. (The length of cotyledons was 0.9 to 1.0 cm. Two very small transparent scales, rudiments of the first pair of leaves, on the swelling may be seen with binoculars. These scales are sometimes absent).
4. Seedlings barely sprouted and above the soil surface. (The length of the partially green cotyledons is 0.5 to 0.6 cm. Some seedlings have curved, yellowish, folded cotyledons. Under binoculars the swellings between cotyledons and the rudiments of the first leaves are absent).
5. Seed balls were forced to germinate on filter paper. When the tip of the radicles had scarcely appeared the seed balls were plunged into colchicine solution for 5.5 hours. The treated seed balls were washed and planted in pots.

Table 2.—Effect of Colchicine Treatment on Seedlings of Different Ages.

	Colchicine Concentration										
	0.5 percent					0.3 percent					0.1 percent
	Age group					Age group					Age group
	1	2	3	4	5	1	2	3	4	5	5
Percent 4*n* plants	0	5.0	10.0	12.5	—	2.9	3.7	13.3	29.4	40.0	42.8
Percent survival	72	70	90	38	6.6	80	80	47	34	12.5	38.0

The survival of seedlings and the rate of growth decreased when the youngest seedlings were treated. The youngest seedlings were damaged more than older seedlings at 0.3 percent and 0.5 percent colchicine.

The highest number of dwarf plants was observed in the fourth group. The percentage of seedlings which survived after seed treatment was still lower. The seedlings which survived after the seed treatment (age group 5) appeared still more sensitive and were damaged more by colchicine than a similar treatment of the youngest seedlings. The number of unaffected plants were considerably higher than when seedlings were treated. Part of the plants had very thick hypocotyls and perished in two to three weeks. Such a condition was not observed in treated seedlings (age groups 1 to 4).

The percentage of $4n$ plants obtained after treatment of seedlings of different ages showed a clear picture with increasing effect of treatment as the age of the seedlings decreased (Table 2). Treatment of the youngest seedlings produced the highest percentage of $4n$ plants, while treatment of germinating seed (age group 5) produced still more tetraploids. The age of seedlings appeared to be a determining factor in colchicine treatment.

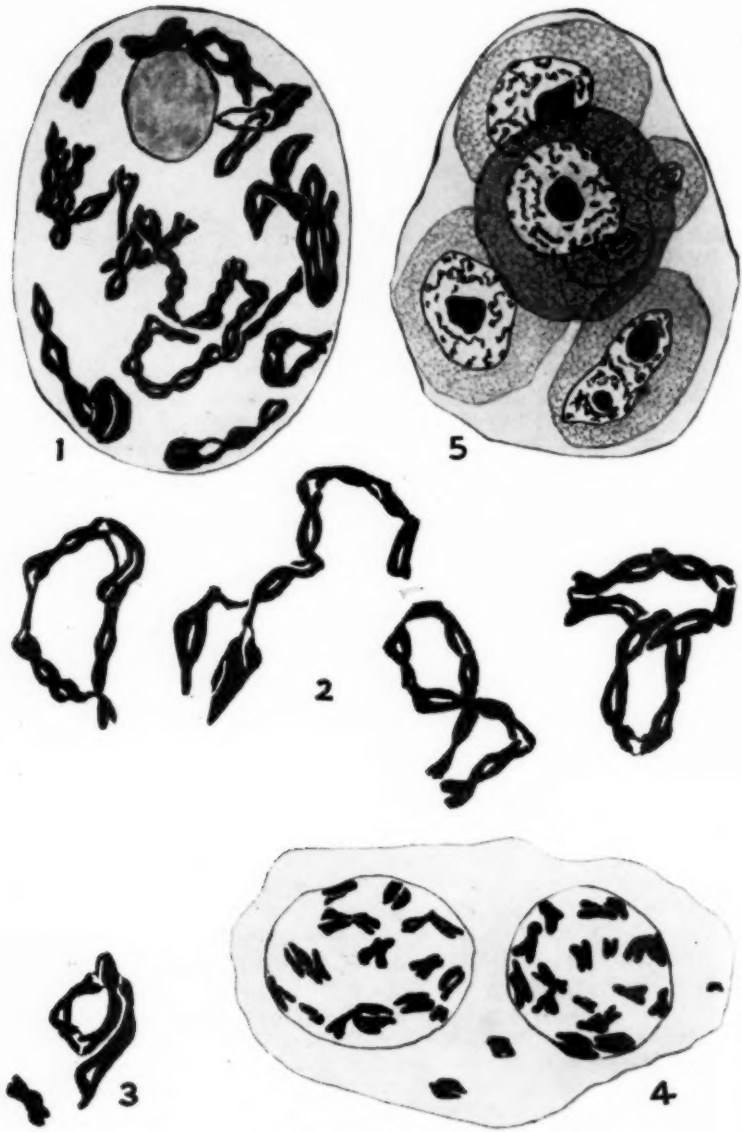
The less the quantity of initial cells which undergo treatment the higher the chances are of obtaining pure tetraploid plants.

It is very important to discard all seedlings unaffected by colchicine and to leave for further work only affected ones. But we cannot count much on attempts to select tetraploids according to their morphological appearance, or investigation of vegetative tissues. From 72 plants showing superficial tetraploid characteristics (thickened, dark green leaves) selected among treated seedlings, only 6.4 percent were found to be true tetraploids with diploid gametes. A large group of other plants which had the general appearance of ordinary diploids produced 8.2 percent of tetraploid plants. A group of 70 plants with large stomata was selected; only 11 of them produced diploid gametes. Nearly 100 percent of the seedlings in all of the experiments were affected. Probably all of them developed chimeral tissue, but only certain ones produced diploid gametes.

It is more satisfactory to select tetraploid plants after treatment according to the size of pollen grains, because this is the only character which indicates the kind of progeny which will be produced by the given plant. It is difficult to agree with the opinion that the considerable variation in the size of pollen grains makes this character uncertain for recognizing tetraploids (6). The pollen must be taken for measurement only when the anthers are dehiscing, *i.e.*, at the time when pollen grains reach their full size. For the majority of diploid plants the size of pollen grains at this time is 18.7 to 21.8u, and in tetraploids the size of pollen grains reaches 28.0 to 31.2u. Variation in size of some pollen grains may occur, but they cannot obscure the general picture of the kind of pollen produced by the given plant.

Tetraploid plants often produce some small defective pollen grains, but a large percentage of large diploid pollen shows without doubt that it is a tetraploid plant. If a plant produces only a few large diploid pollen grains and the size of the remaining pollen is comparable in size with haploid pollen grains, it is highly probable that such a plant is a chimera and must be discarded.

The progeny obtained from selected tetraploid plants must be checked as to chromosome number.



Figures 1 through 5.—Meiosis in 4*n* Plants.

(Descriptions of these figures appear on page 475)

Considerable irregularity was observed in meiosis in tetraploid plants. Chromosomes for the most part were associated in pairs (bivalents). Some chromosomes formed quadrivalents and trivalents (Figures 1, 2, 3). During the first metaphase certain chromosomes were forced out into plasma. The nuclei after the first division contained at interkinesis 18, 17, 16, 15 and 14 chromosomes (Figure 4). Besides the diploid gametes containing 18 chromosomes, the tetraploid beets produced gametes with different numbers of chromosomes. Many of the tetrads were normal and contained four nuclei, but some tetrads contained five, six and seven nuclei (Figure 5). A considerable number of small degenerating pollen grains side by side with normal large diploid pollen grains were formed. These small pollen grains contain fewer chromosomes than the diploid set and were not viable. Therefore, in spite of considerable irregularity in meiosis, sugar-beet tetraploids produce for the most part tetraploid progeny, but some aneuploids can always be expected among them.

Summary

Studies were made to determine the importance of colchicine concentration, duration of treatment and the age of seedlings at which the treatment was the most effective. The best concentration for seedling treatment was considered to be 0.3 to 0.5 percent colchicine. Increased concentration and duration of treatment beyond 7.55 hours were not important. The age of seedlings appeared to be a determining factor in colchicine treatment. The youngest seedlings developed the highest percentage of tetraploid plants. Size of pollen grains was considered better than investigation of vegetative tissues for recognizing tetraploid plants after treatment.

Irregularities in meiosis in tetraploids may lead to appearance of some aneuploids in their progeny.

Meiosis in 4*n* Plants

Following are descriptions of Figures 1 through 5, which appear on page 474.

Figure 1.—Diakinesis with three quadrivalents and 12 bivalents. x 7,500.

Figure 2.—Quadrivalent associations. x 8,000.

Figure 3.—Trivalent association plus univalent. x 8,000.

Figure 4.—Interphase-nuclei with 18 and 16 chromosomes, two chromosomes and fragment in plasma. x 7,500.

Figure 5.—Tetrad containing six cells. x 3,180.

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An Improved Method for Packing Sugar Beet Roots to Be Stored for Breeding Purposes

J. M. Fife and Charles Price[1]

Introduction

In most sugar beet breeding programs the rigid selection of roots usually results in a relatively small number being saved for seed increase. It is highly important, therefore, that all or as many as possible of the selected roots be carried through the required thermal induction period, in storage, in a condition to produce satisfactory yields of seed. Pack (1)[2] studied methods of storing sugar beet roots in field silos or pits in Utah, where the winters are comparatively cold, and preferred storing the roots in moist sand to other materials tried. Such methods of storing sugar beet roots in silos are not feasible in southern California where the winters are so mild that the roots do not acquire sufficient thermal induction for normal seed yields. It is necessary, therefore, to pack the roots in containers and store them in a room maintained at a constant temperature which is optimum for thermal induction. This has led to the testing of packing materials and methods to meet the somewhat specialized requirements.

Methods and Results

The method previously used for packing sugar beet roots at the U. S. Sugar Plant Field Station at Riverside, California, was as follows: Sphagnum moss was submerged in water until it became saturated. Part of the free water was removed by hand pressure. A layer of the moss was then placed in the bottom of an orange field box 24 inches x 12 inches x 12 inches lined with two sheets of heavy waxed paper. The boxes were filled with alternate layers of wet moss and roots, the top layer being moss. The ends of the paper were then tucked into the ends and sides of the box which completed the packing process. Usually, the sugar beet roots are stored at 40° F., the length of the storage period depending upon the time of year selections are made and upon the time required for the roots to acquire sufficient thermal induction to induce bolting.

With the above method of packing, the length of time the roots would remain sound at 40° F. was highly unpredictable. It has been observed many times that the amount of rot occurring in different boxes of roots packed at the same time varied greatly. A large variation in the amount of rot even in different layers of the same box of roots was found to occur. In one test a large number of roots was packed by the above method in several boxes and stored. The roots in part of the boxes remained in storage for 130 days with only small losses. In other boxes 50 to 80 percent of the roots were lost in a period of 90 days.

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[2] Numbers in parentheses refer to literature cited.

It was observed that in almost all instances where early and excessive rot occurred the moss was so wet that with little effort one could squeeze water from it at the end of the storage period. It may be, therefore, that if beets were packed in moss with a uniform and favorable moisture content losses could be reduced below those which have been encountered. However, in practice it probably would be necessary to resort to the use of a mechanical press in order to reduce the moisture content of the moss to a sufficiently low level for best results.

Sawdust and pine shavings were tested as packing material to replace sphagnum moss. Sawdust was abandoned after preliminary tests because of the excessive amount of water it held and the limited amount of air space it afforded. The favorable water-holding capacity of pine shavings and the fact that they are clean and relatively sterile make them appear to be highly suitable as a packing material. Numerous tests have been made with pine shavings in which they were compared with sphagnum moss.

The method used in packing beets in pine shavings is as follows: A small stream of water from a garden hose is allowed to run into the top of a bag of the shavings until they are completely saturated. The shavings are allowed to drain one to two hours or until little or no water drips from the bag. They are then spread out on a concrete floor and approximately ten percent (by volume) of dry shavinsg mixed with the wet shavings with the aid of a scoop shovel. The dry shavings take up the remaining free water. Orange field boxes, lined with two sheets of heavy brown waxed paper placed at right angles to each other, are filled with alternate layers of the prepared shavings and sugar beet roots until the box is full. A layer of the prepared shavings approximately two inches thick is placed in the bottom of the box and over the last layer of roots. The ends of the inside paper are folded over while the ends of the outside paper are tucked into the sides of the box, making a complete envelope of wax paper for the pack.

In some of the tests which have been made, beets of like size and from the same sources were packed in sphagnum moss and in pine shavings and their condition compared after various periods of storage. The method of packing the roots was the same for both materials used except that the moisture content of the pine shavings was adjusted to approximately 90 percent of saturation, while the usual procedure was followed (that of expressing part of the free water from the moss by hand pressure) in packing the roots in sphagnum moss. The packed roots were stored at 40° F. and received no further attention until they were examined at the end of the storage period.

In Table 1 are compiled data on the number of roots showing decay and the extent of the damage at the time the roots were removed from storage. The tests are arranged according to the number of days the roots were in storage before being examined.

It is seen from the table that by the end of 180 days of storage more than 800 roots, packed in moist shavings, had been examined and none

showed obvious decay. When the storage period had reached 243 days, however, some of the roots showed small decayed spots, but all were turgid. It was not until the roots had been stored for 300 days that the amount of decay on the roots became more than small superficial spots.

The roots packed in sphagnum moss on 11-5-49 were from the same lot of roots as those packed in moist pine shavings on the same date. Roots stored for 134 days in sphagnum moss showed extensive decay. Few if any of these roots if planted in the field would have survived. Representative samples of beets stored in moss for 134 days are shown in Figure 1B. These may be compared with roots stored in pine shavings for 167 days, shown in Figure 1A.

Table 1.—Amount of Decay on Sugar Beet Roots Stored at 40° F. for Various Periods in Sphagnum Moss Compared with Those in Pine Shavings.

Packing material	Date packed	Storage period	Boxes used	Roots stored	Roots showing rot at end of test			Total roots showing decay
					Slight	Medium	Severe	
		Days	No.	No.	No.	No.	No.	No.
	9-19-49	60	7	150	0	0	0	0
Pine	1- 5-50	66	3	70	0	0	0	0
shavings	4-14-49	97	1	15	0	0	0	0
	3-23-49	118	1	15	0	0	0	0
	11- 5-49	128	10	128	0	0	0	0
Sphagum	11- 1-48	130	35	1,500	—	—	260	—
moss	11- 5-49	132	1	20	6	5	9	20
	11- 5-49	134	1	25	5	7	13	25
	11- 5-49	134	10	300	0	0	0	0
	11- 5-49	148	4	80	0	0	0	0
	11- 5-49	180	4	100	0	0	0	0
Pine	3-11-50	191	4	166	1	0	0	1
shavings	11- 5-49	243	2	55	3	0	0	3
	11- 5-49[1]	243	1	22	11	0	1	12
	3-11-50	254	3	46	9	0	2	11
	11- 5-49	296	1	27	3	0	1	4
	6-14-50	355	1	13	2	0	0	2
	11- 5-49[1]	367	1	22	7	0	1	8

[1] Same lot of roots. Decayed spots were cut away before repacking after 243 days of storage.

Another interesting comparison between moss and pine shavings may be cited, in which part of the roots were first packed in moss and later repacked in pine shavings. In this test 66 roots were packed in seven boxes in the usual manner, using wet sphagnum moss as the packing material. At the same time four other root selections, comprising a total of 457 roots, were packed in moist pine shavings. The moisture content of the shavings was adjusted to approximately 90 percent of saturation by the mixing of dry shavings with those saturated with water. The roots were stored at 40° F.

After a period of 60 days all roots were removed from storage and examined. Of the 457 roots stored in shavings none showed rot. These roots were repacked for shipment. However, all 66 roots packed in sphag-

Figure 1.—A. Sugar beet roots after being stored 167 days at 40° F. in pine shavings (90 percent saturation). B. Sugar beet roots after being stored 134 days in wet sphagnum moss.

num moss showed decay varying from small superficial spots to almost complete invasion. Thirty-five of the roots were discarded. The remaining 31 roots were trimmed to remove all the decayed tissue, allowed to stand overnight to permit the cut surfaces to dry, then packed in moist pine shavings and stored at 40° F. for an additional 190 days. At the time these roots were transplanted in the field, after a total of 250 days in storage, none of the repacked roots had to be discarded due to excessive decay, although some of them showed decayed spots.

It was observed that in nearly all cases of decay, occurring in roots stored in pine shavings, the decay started at the tip of the roots or on bruised areas caused by injury in digging. The amount of decay occurring on roots stored for long periods of time can be greatly reduced if the roots are prepared properly before they are packed. The roots should be dug and handled carefully to prevent bruising. The leaves should be trimmed off as closely as possible without destroying the buds and the root, then washed thoroughly. Bruised spots, if any, should be trimmed off and the tails removed at a point where they attain approximately one-half inch in diameter. The roots should then be allowed to remain in the open, preferably overnight, in order to allow the cut surfaces to dry before they are packed. By using the above precautions, roots stored up to 200 days have shown practically no decay and they have remained turgid for 250 days (in one instance 355 days) without repacking, or the addition of moisture. If the roots are to be stored longer than 250 days it may be necessary to repack them in moist shavings in order to keep them turgid. Attempts to moisten the pack by the addition of water to the top resulted in losses because of the fact that the water was slow to distribute itself throughout the shavings in the pack. As a result, the roots in the top of the box remained drenched for a time.

Pine shavings seem to have several advantages over sphagnum moss as packing material for storage of sugar beets. They are usually readily available at a very low cost from any planing mill or cabinet shop. They are relatively free of dirt and probably of microorganisms which produce rot. They are easily brought to any desired moisture content relative to saturation. Furthermore, they give up moisture to the roots to such an extent that the roots were still fresh and turgid even though the shavings had lost more than 80 percent of the moisture held at packing time.

Summary

Rots occurring in sugar beet roots, stored at a temperature suitable for thermal induction (40° F.), were found to be greatly accelerated by the presence of free water in the packing material. Moist pine shavings were found to be superior to sphagnum moss as packing material.

Roots packed in pine shavings having a water content equal to 90 percent of saturation showed no obvious rot at the end of a storage period of 180 days at 40° F. and showed very little rot after 243 days. Pine shavings gave up moisture to such an extent that roots stored 250 days and even for longer periods at 40° F. were still fresh and turgid although the shavings had lost more than 80 percent of the moisture held at packing time.

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Report of Indexing of Inbreds[1]

Cooperative indexing of inbreds is one phase of a breeding program which sugar beet breeders are coming to recognize as inevitable if many essential or desirable characters are to be incorporated into any commercial variety in a reasonable length of time. This concept has become generally recognized. It follows the successful development of commercial varieties resistant to the two principal diseases in the United States—curly top and leaf spot—and coincides with the development of practical methods for testing certain other characters, and the acquisition of some new ones such as monogerm seed and male sterility.

The method of breeding by selection in inbred lines followed by hybridization for commercial release, so successfully used by the corn breeders, appears to be the only method adequate for the present sugar beet breeders' problem. Over a quarter of a century ago the corn breeders developed a coordinating agreement and organization (3)[2] which has been recently recognized by R. A. Crabb (1) as one of the principal reasons for the phenomenal success attained with hybrid corn.

Further significance has been given to the inbreeding method by R. A. Fisher (2) using a statistical approach in which he concludes: "—as the basis for future livestock and plant improvement there is required not a single inbred line, or a few only, but a deliberately planned multiplicity. The price paid for reliability of breeding behavior is the impoverishment of the genic content, due to the elimination of many genes. There need be no such impoverishment if many inbred lines are created simultaneously." Fisher cites as an example hybrid corn: "—in which thousands of inbred lines have been produced.'" He further states, "In species in which so far only a few inbred lines have become available, success has not been conspicuous."

Historical

A cooperative program supported by all interested parties for the development and testing of the required number of inbred lines and hybrids appears to be the only practical solution to the problem of handling the large volume of testing work involved in the development of commercial hybrid sugar beet varieties.

At the 1950 summer meeting of the Advisory Committee for the Curly Top Resistance Breeding Committee the need for cooperative effort on the problem of testing and indexing inbred lines for many characters was discussed. This was followed by a meeting at Beltsville, Maryland, February 1-3, 1951, of an informal so-called "Breeder's Forum" with Bion Tolman of the Utah-Idaho Sugar Company serving as chairman by action of the group. Mr. Tolman summarized the events and discussions at this meeting in a very comprehensive report. Several points were agreed upon and recommended, among these being:

[1] Report of committee meetings outlining and developing a program for indexing of inbreds.

[2] Numbers in parentheses refer to literature cited.

1. A definite cooperative program be set up for the indexing of inbred lines for many characters.

2. A summer meeting be held to visit the United States Department of Agriculture work at Fort Collins and such cooperative tests as possible.

3. That the "Breeder's Forum" be reconstituted as an industry-wide committee

4. Mr. Tolman was reelected to continue as temporary chairman for 1951 until such time as the committee might be reorganized.

Later developments included the acquisition of 50 inbred lines for cooperative indexing; specific plans for testing these at three locations, viz., Rocky Ford and Longmont, Colorado, and Sheridan, Wyoming; a definite date (September 10-13) for a summer meeting, and the assignment for coordination of these activities to H. E. Brewbaker.

The Beltsville meeting was attended by G. H. Coons, Dewey Stewart, J. S. McFarlane and Geo. Arceneaux (U.S.D.A.), H. L. Kohls (Michigan State Experiment Station), C. W. Doxtator (American Crystal Sugar Company), C. A. Lavis and Don Peterson (Holly Sugar Corporation), G. S. Rush (Amalgamated Sugar Company), Bion Tolman (Utah-Idaho Sugar Company), H. E. Brewbaker (Great Western Sugar Company) and Henk Rietberg of the Netherlands.

At the summer meeting thirty-three people attended, including representatives from U.S.D.A., 10; Farmers & Manufacturers Beet Sugar Association, 1; Colorado A & M College, 1; International Minerals & Chemicals Corporation, 2; Canada Sugar Factories, 1; Utah-Idaho Sugar Company, 2; Amalgamated Sugar Company, 1; Spreckels Sugar Company, 1; Holly Sugar Corporation, 3; American Crystal Sugar Company, 6; and the Great Western Sugar Company, 5. The group observed the testing plots at Rocky Ford and Longmont, Colorado. One day was spent looking over the U.S.D.A. plots at Fort Collins, Colorado.

Report of the Proceedings at the A.S.S.B.T. Meeting, Salt Lake City, February 4-7, 1952

Two sessions were held—the first being a panel discussion of the inbred indexing program, with particular reference to the principles involved, and the other an informal round table to discuss methods and future testing.

The members of the panel included C. W. Doxtator, D. F. Peterson, G. W. Deming, R. K. Oldemeyer (Secretary), H. L. Kohls, F. V. Owen, Lucile Hac and H. E. Brewbaker (Chairman).

Included in the cooperative studies with tests at three locations, as indicated above, were three inbreds from the U.S.D.A. Station at Salt Lake City contributed by F. V. Owen, 37 from the U.S.D.A. at Fort Collins, Colorado, by G. W. Deming, and 10 from the Michigan State Experiment Station by H. L. Kohls. The origin of these were discussed by the contributors with comments as follows:

F. V. Owen cited the use of the Connecticut method involving the lumping together of several good lines and selecting on a wide basis as a

possible method for securing large numbers of inbred lines. He also cited the use of the self-fertility (S^f) gene in inbreds to facilitate selfing.

G. W. Deming reported that about one-third of his lines were derived from "Flat Foliage" tracing to R & G numbers. Others were derived from Hilleshog, Cesena, Frederikson and red garden beet. A number of the lines are five to eight generations selfed. Selfing was accomplished by space isolation or bagging with no particular attention paid to the self fertility, S^f gene. Seed for testing was produced by sib-pollination.

H. L. Kohls reported that his lines were up to seven generations selfed, and were inbred only to uniformity. In early work all roots were tested for sugar, this being eliminated in recent years. A number of lines stem from Dippe. The lines were increased by sib-pollination.

Field Tests

Field tests at Rocky Ford, Longmont and Sheridan were planned as triple-rectangular lattice designs with three replications, in plots four rows wide x 25 feet long. The field plan was identical for each test, the results being discussed respectively by C. W. Doxtator (Am. Cr. Sugar Co.), R. K. Oldemeyer (G.W.) and Don Peterson (Holly). Stands were very poor at Rocky Ford, the result of two heavy hail storms; fairly good to excellent at Longmont, and generally excellent at Sheridan. Soil fertility and cultural conditions were of good uniformity for each field, and there was no material amount of leaf spot or other serious complicating diseases at any of the locations. For these reasons these tests may be regarded as rather satisfactory as a basis for indexing this series of inbreds for a number of characters.

Table 1.—Correlation Coefficients Determined from Data in the 1951 Inbred Indexing Program.

	r values		
Characters	**Longmont**	**Sheridan**	**Rocky Ford**
Na, Sugar	—.7568	—.6415	—.8160
Na, Yield	.2587	.0725	.....
Na, K	.5271	.4781	.1892
K, Sugar	—.4748	—.5301	—.4588
K, Yield	.3495	.1580	.....
Yield, Sugar	—.1802	.1489	.....
Total N, Yield	—.1788	.....	.....
Total N, Sugar	—.1561	.....	.....
Total N, Na	.2799	.....	.....
Total N, K	.2672	.....	.....
Total N, Raffinose	—.1932	.....	.....
Raffinose, Yield	.1587	.....	.....
Raffinose, Sugar	—.3248	.....	.....
Raffinose, Na	.3679	.....	.....
Raffinose, K	—.0185	.....	.....
	Sheridan Longmont-	**Rocky Ford Longmont-**	**Rocky Ford Sheridan-**
Yield	.6722	.....	.....
Sugar	.6922	.7918	.6489
Na	.8035	.7821	.8712
K	.8094	.5674	.4123

r for significance at 5% point = .276
r for significance at 1% point = .358

In addition to the sugar and yield tests at Longmont, Colorado, and Sheridan, Wyoming, sodium, potassium, nitrogen, raffinose and glutamic acid content were determined for each of the fifty lines. Respiration and storage rot resistance tests were also made. Extremely wide variations were noted for every character.

H. L. Bush (Great Western Sugar Co.) discussed the correlation coefficients he calculated from the data reported. The *r* values are reported in Table 1.

The rather high positive *r* values existing between locations, if they continue to hold, may allow the reduction in number of tests, at least for yield and sugar content.

The glutamic acid determinations had not been made at the time of the meetings. Dr. Lucile Hac of International Minerals & Chemicals discussed briefly previous investigations involving 43 inbreds furnished by Deming. A complete report is given in this Proceedings. She pointed out the large variation between lines and the lack of correlation between percent of sucrose and G.A. In this connection, Dr. Coons (U.S.D.A.) reported U. S. 216 to be high in both G.A. and percent of sucrose. Dr. Hac noted that G.A. content may tell something about the amount of nitrogen available to the beet. Low sugar, high G.A. indicates too much nitrogen; high sugar, low weight and low G.A. indicate too little nitrogen.

Variability in inbred lines appears much greater for weight of root than for some chemical characters. "Climate" studies at Earhart Laboratories, California Tech., were cited as showing wide variability in size of root for certain inbreds used. Dr. R. K. Oldemeyer gave a theoretical explanation of this in which he pointed out how the segregating of one size gene might result in considerable variation in weight of root, and he ascribed obtained variability to 1. gene segregation in a below optimum gene complex, and/or 2. poor adaptability of inbreds to variations in environment.

Round Table on Methods and Further Tests

This meeting, held February 7, consisted of an informal discussion mainly of details in connection with further cooperative efforts on indexing.

Seed and Roots for Inbreds Tested in 1951

For any further testing, there was insufficient seed of some lines and ample seed of others as reported by the three suppliers—Owens, Kohls and Deming. Kohls has an ample supply. Roots were saved of all lines at Longmont and Sheridan. Some but not all of these will be increased as reported by Brewbaker and Peterson. Seed could be made available from these increases to others.

Further Testing

Locations for field tests in 1952 were agreed on as follows:

1. Longmont, Colorado, Great Western Sugar Company
2. Sheridan, Wyoming, Holly Sugar Corporation
3. Idaho Falls, Idaho, Utah-Idaho Sugar Company

Figure 1.

Rocky Ford was not included for the 1952 tests because of rather great danger of leaf spot there, and the desire to have one test west of the Rockies. For other characters:

Bolting, Spreckels Sugar Company
Rust, Spreckels Sugar Company
Downey mildew, Spreckels Sugar Company
Seedling damping-off, Colorado A & M College, N. Gerhold
Seedling damping-off, Montana Experiment Station, M. M. Afanasiev
Aphanomyces resistance, American Crystal Sugar Company
Cold resistance—germination and seedling stage, Great Western Sugar Co.
Curly top resistance, U.S.D.A., F. V. Owen
Leaf spot resistance, U.S.D.A., J. Gaskill
Male sterility indexing, supplier of inbred
Sugar beet nematode, Henk Rietberg

For the 1952 tests, 53 inbred lines are available. Deming (U.S.D.A.) will supply 26, Kohls (Mich. State Exp. Sta.) 14, Great Western Sugar Co. 5, McFarlane (U.S.D.A.) 1, and Owen (U.S.D.A.) 7.

Policy Regarding Ownership of Inbreds and Basis for Interchange

Dr. Wadleigh (U.S.D.A.) proposed each contributor retain ownership, and that interchange be on the basis of mutual and individual agreement. Also, for inbred lines contributed from organizations supported by public funds, it was proposed that full credit be given in all publications. Credit for use of inbred lines contributed by companies shall be given in all scientific publications and in company publications, at the discretion of the company. This basis of agreement was generally acceptable.

Discussion—Various Characters

In answer to the question of whether all lines should be indexed for each character, Dr. Rietberg stated that they should be because some other-

wise undesirable line may be outstanding for some other valuable character.

Mrs. Savitsky stated that degree of self-fertility should be determined in an area not conducive to pseudo-self fertility. Dr. Downie suggested finding locations conducive to pseudo-self fertility for bagging operations so that the S^f gene would not be necessary.

Male sterility indexing.—Dr. Owen suggests planting male steriles in increase plots to index for xxzz. Mr. Kohls felt that four or five roots were insufficient for this test.

Weight of tops.—Dr. Doxtator wants tops actually weighed, rather than a categorical estimate of "top vigor." Mr. Kohls was not interested in top weights.

Records

There was some discussion of the form which permanent indexing records should take. A difference of opinion exists re—actual versus categorical ratings for various characters. Both ratings were provided at the meeting which may continue to be desirable if after careful consideration this difference of opinion continues to exist.

In the meantime, some convenient and workable system of recording needs to be worked out so that all of the data (actual or categorical) can be briefly summarized for each line for efficient use by breeders. Can it take the form of ordinary file card (one per line), I.B.M. cards with a maximum of ease for sorting, "Visible" system equipment, ordinary summary pages, etc.? Here is an opportunity for some filing ingenuity, for such records can become extensive and unwieldly if the system set up is inadequate for large numbers.

Such a recording system should provide space for a photograph, at least 2¼ inches x 3¼ inches in size, taken in the field to show eight to ten beets in front of an unharvested portion of each plot as, for example Figure 1.

Dr. H. E. Brewbaker was elected chairman for the 1952 season with Dr. C. W. Doxtator to be chairman pro-tem in absence of the chairman.

Yield, sugar percentage and chemical analysis summaries for the 1951 tests are available upon request from the Great Western Sugar Company, Agricultural Experiment Station, Longmont, Colorado.

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ENTOMOLOGY
AND
PLANT PATHOLOGY

Experiments on Control of the Sugar-Beet Root Maggot[1]

E. W. Jones, J. R. Douglass, C. P. Parrish and Vernal Jensen[2]

The sugar beet root maggot (*Tetanops myopaeformis* (Roeder)) was first described by Roeder in 1881 from specimens collected at Sacramento, California. Towley (2)[3] was the first to report this insect as a pest of sugar beets from observations made near Amalga, Utah, during July, 1920. Maxson (4) reported that it had caused serious injury to sugar beets in Alberta, Canada; northern Colorado, Idaho, Montana, Wyoming and Utah. Essig (1) called this insect the sugar-beet ortalid, since it belongs to the family Ortalidae, "the picture winged flies." He reported that H. H. P. Severin had noted it injuring sugar beets in California. Hawley (2) reported that flies of this species had been collected at Burns, Oregon, and Moscow, Idaho, and stated that it was apparently a native insect which had fed for many years on such weeds as lamb's-quarters (*Chenopodium album* L.), red root (*Amaranthus retroflexos* L.), and prostrate pigweed (*A. blitoides* S. Wats.). In addition, it has been observed breeding on black nightshade (*Solanium nigrum* L.).

Thorn and Jensen (5) used ethylene dibromide for the control of the sugar-beet root maggot in 1947, and later Jensen and Parrish (3) showed that this soil fumigant was effective in controlling the maggot when applied as a side-dressing.

Nature of Injury

The sugar beet root maggot feeds by rasping. It eats the tap and feeder roots of the beet plants and often cuts off these roots. From the injured roots plant juices escape, causing the tissues to turn black at the wound and the soil to become moist about the injury. When the tip of the tap root is eaten off, the plants wilt during the heat of the day and many of them die. Infestations are heaviest in fields where sugar beets follow beets or in fields adjacent to last year's beet fields.

The major injury to sugar beets is done by first generation maggots while the beets are small. In severe infestations, from 80 to 90 percent of the beet stand may be killed, as shown in Figure 1, and the stand loss occurs so late in the season that replanting is not practicable.

Life History

In southern Idaho the sugar beet root maggot passes the winter as a full-grown maggot in the soil of old beet fields. These overwintering maggots are found concentrated along the old beet rows, as many as 60 per square foot. As the sun warms the soil in early spring, the maggots move slowly toward the surface, where they pupate at a depth of one to three inches about the middle of April. Adult flies begin to emerge about May 10 and reach the peak about May 20. Most of the eggs are laid during the latter

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[2] E. W. Jones and J. R. Douglass, U. S. Department of Agriculture, Agricultural Research Administration, Bureau of Entomology and Plant Quarantine, and C. P. Parrish and Vernal Jensen, the Amalgamated Sugar Company.

[3] Numbers in parentheses refer to literature cited.

Figure 1.—Field of sugar beets at Rupert, Idaho, on July 18, 1951. The beets at the left were treated with ethylene dibromide for the control of the sugar-beet root maggot, and those at the right were untreated.

half of May. The eggs are laid in clusters of 10 to 20 about ¼ inch deep in the soil around the stems of the plants. The eggs begin to hatch about June 1, and the maggots crawl down the beet to feed on the roots. Most of the maggots continue to feed for the remainder of the season and work their way deeper into the ground, where they pass the winter. It requires about a month for the development of the first generation of maggots. A few early maturing maggots pupate about July 1 and give rise to a small second generation of flies during August and early September.

Methods

The three methods used in the control of the sugar beet root maggot were seed treatments, soil treatments and fumigation. These experiments were conducted on sugar beets growing in sandy loam soil in the Rupert, Idaho, area during 1950 and 1951. The randomized-block method was used in setting up the experiments, and tests were run in four-row parallel plots 400 to 500 feet long. The treatments were replicated four times in 1950 and five times in 1951. During the first week of March a survey was made to determine the overwintered maggot population in the previous year's beet fields, so that the fields expected to have an infestation could be selected for the experiments in June.

In the soil-treatment method the insecticides were mixed with phosphate fertilizer in a roller-drum mixer. The mixtures were broadcast with a spreader over the soil surface at the rate of 100 pounds per acre and were harrowed lightly into the soil on March 29, 1950, and on April 5, 1951.

In the seed-treatment method the dry insecticides were dusted over the seeds in a bag, which was shaken and tipped in the field just prior to planting. The treated beet seed was planted with a four-row plate-type beet and bean planter. At the end of each plot the seeds in the planter can were removed to the bag and shaken and then replaced in the planter can. A sufficient amount of insecticide adhered to the seed in this method, and the excess material was distributed into the furrow with the seed.

In the soil-fumigant method, ethylene dibromide was diluted with kerosene at the rate of 1¾ to 8¼ gallons to increase the volume for even distribution, and 10 gallons of the mixture were injected per acre. Since ethylene dibromide is heavier than kerosene, it was thoroughly mixed before being pumped into the applicator tank. The applicator, mounted on a tractor, applied the fumigant as a side-dressing to four rows at a time. The fumigant was applied six inches below the soil surface and six inches to both sides of the row.

Seeds of Improved U. S. 22 curly top-resistant variety of sugar beets were used both years. These seeds were treated with a fungicide 2.3-dichloro 1,4- Naphthoquinone in 1950 and thiram in 1951. The fields for the soil and seed treatments were planted on March 31 and April 17, 1950, and on April 9 and 16, 1951. The fumigants were applied on June 1 and 12, 1951.

The number of plants injured by the maggots was determined by examining plants taken at random from the center rows of each four-row plot. Where the plants had been thinned, 50 beets were examined in each treatment; and where they had not been thinned, approximatly 50 beets were examined. The beets were examined on June 26 and 30, 1950, and on June 11 and 14, 1951. The stand of beets was determined by counting all plants in the plots just prior to harvesting. All beets were harvested mechanically. The yields given in the tables are for clean beets, the weights of which have been converted from plot yields to yields per acre. The beets were harvested from October 23 to 30, 1950, and from October 24 to 27, 1951.

Insecticides Tested

The following insecticides were tested:

Aldrin	Heptachlor
Chlordane	Lindane
Dieldrin	Parathion
DDT	Toxaphene
Ethylene dibromide	

All the materials except ethylene dibromide were wettable powders containing 25 to 50 percent of toxicant by weight. The ethylene dibromide was a liquid containing 83 percent by weight of ethylene dibromide, or 12 pounds per gallon.

Before the field experiments were planned, exploratory tests were conducted in the greenhouse to determine what effect, if any, insecticides would have upon the germination of beet seed. These tests showed that it was safe to treat sugar beet seed at the dosages used.

Discussion of Results

The effectiveness of the treatments was based upon three criteria—percentage of beets injured by the maggots, plant stand and yields.

Experiments in 1950.—The results obtained in both the soil- and seed-treatment field experiments in 1950 are presented in Table 1. In both experiments aldrin gave, in general, the least maggot injury, the best stands and the largest yields. The increases in yield over the checks in the soil and seed treatments were 2.61 and 2.50 tons per acre. Although these gains were not significant, they showed the possibility of controlling this insect by both treatments.

Experiments in 1951.—The field in which the soil-treatment experiment was conducted in 1951 was divided into two portions for crop-rotation purposes. Beans had been grown on the east portion of the field in 1950 and were followed by beets in 1951. The west portion of the field was in beets in 1950 and was followed by beans in 1951. This old beet field contained a high population of overwintered maggots and was the principal source of infestation. As the flies emerged from the bean field, they moved with the wind into the adjoining beets. The density of maggot infestation in the beets decreased as the distance from the bean field increased. The beets nearest the beans were infested earlier, and the injury to the seedling beets was evidently greater in the plots adjoining the beans, as shown in Figure 2. In general, the stand of beets and its uniformity increased across the field from the beans. The average yields of beets per block across the plots, beginning on the side adjoining the beans, were 9.2, 10.4, 13.8, 18.3 and 18.5 tons per acre, which substantiates the above conclusions.

Table 1.—Effectiveness of Soil and Seed Treatments for the Control of the Sugar-beet Root Maggot on Beets, 1950.

Insecticide	Toxicant[1]	Average beets injured	Mean stand of beets per 100 feet of row at harvest	Mean yield of beets per acre
Soil treatments				
	Pounds	Percent	Percent	Tons
Aldrin	1	46	87.6	23.22
Toxaphene	2½	62	84.4	22.43
Chlordane	2½	58	85.8	21.73
Lindane	½	54	86.5	21.54
DDT	4	60	86.8	21.11
Untreated	—	48	86.0	20.61
Seed treatments				
Aldrin	¼	65	79.8	23.88
Chlordane	¼	73	77.3	22.45
Chlordane	½	60	77.3	21.38
Lindane	¼	68	69.2	21.38
Lindane	⅛	75	78.1	19.48
Parathion	¼	55	66.4	19.48
Untreated	—	67	77.0	21.38

[1] Pounds per acre for soil treatments and per 100 pounds of seed for seed treatments.

All soil treatments gave increases in yield over the check, as shown in Table 2. Aldrin, dieldrin and heptachlor gave gains of 4.96, 4.68, and 4.32 tons per acre over the check, although they were not significant.

In the fifth replicated block the degree of maggot infestation and injury to the beets was so low that the untreated plot and those treated with

Table 2.—Effectiveness of Soil and Seed Treatments in Comparison with a Soil Fumigant for the Control of the Sugar-beet Root Maggot on Beets, 1951.

Insecticide	Toxicant[1]	Average beets injured	Mean stand of beets per 100 feet of row at harvest	Mean yield of beets per acre
Soil treatments vs. fumigant				
	Pounds	Percent	Percent	Tons
Aldrin	3	14	48.3	15.94
Dieldrin	3	19	52.3	15.66
Heptachlor	2	18	55.1	15.30
Toxaphene	5	69	48.6	14.42
Chlordane	4	21	51.2	14.13
Parathion	2½	47	48.2	14.12
Ethylene dibromide				
Applied June 1	21	27	54.2	13.47
Applied June 12	21	75	54.7	12.48
Untreated	—	57	42.3	10.98
Difference required for significance				
At 5 percent level		30.1	6.7	ns
At 1 percent level		40.4	9.0	ns
Seed treatments vs. fumigant				
Ethylene dibromide				
Applied June 1	21	16	74.2	25.74
Heptachlor	¼	52	75.4	25.41
Aldrin	½	52	75.9	25.35
Dieldrin	¼	62	69.0	23.89
Aldrin	¼	72	69.6	23.80
Parathion	¼	76	66.8	23.41
Ethylene dibromide				
Applied June 12	21	82	72.9	23.06
Lindane	¼	88	61.3	21.65
Chlordane	½	84	63.8	21.53
Untreated	—	98	60.2	20.83
Difference required for significance				
At 5 percent level		19.0	6.7	2.25
At 1 percent level		25.4	9.0	3.02

[1] Pounds per acre for soil treatments and per 100 pounds of seed for seed treatments.

the less effective materials gave, in general, as high yields as the most effective treatments. This block was the farthest from the source of infestation. In this check plot only 29 percent of the beets were injured. By eliminating this block from the statistical analysis, one finds that aldrin, dieldrin, heptachlor and parathion gave highly significant increases in yields over the check. Although parathion was better than the check at the one percent level, it did not give the desired protection under a very severe maggot infestation.

Aldrin, chlordane, dieldrin and heptachlor gave a lower percentage of injured beets than the checks when compared at the 5 percent level, but only aldrin at the 1 percent level. The plots fumigated late with ethylene dibromide and those treated with toxaphene contained more injured beets than the checks. All treatments except aldrin, parathion and toxaphene gave better plant stands than the checks at the 5 percent level, but only dieldrin, ethylene dibromide and heptachlor at the 1 percent level.

Figure 2.—The soil-treatment experimental plots at Rupert, Idaho, on July 16, 1951. Six rows adjoining the beans on the left were untreated, and the four rows to the right of stake "H" were treated with heptachlor.

Although the differences required for significance are given at two levels, the discussion of the data on the seed treatment is based upon the 1 percent level. Aldrin, dieldrin, ethylene dibromide (June 1 application), and heptachlor gave a lower percentage of beets injured than the checks. Aldrin, ethylene dibromide and heptachlor gave better stands than chlordane, dieldrin, lindane, parathion and the checks. Aldrin, at ½ pound per 100 pounds of seed; dieldrin, ethylene dibromide (June 1 application), and heptachlor gave gains in yield of 4.52, 4.91, and 4.58 tons per acre over the check.

The average percentage of beets injured by the maggots in both of the ethylene dibromide applications on June 1 was 21.5, as compared with 78.5 percent for the June 12 application. The June 1 application gave gains in yield of 0.99 and 2.68 tons per acre over the June 12 treatments. This shows that in 1951 the critical period for applying soil fumigant for the control of this maggot was above June 1 in the Rupert area.

Messrs. Jensen and Parrish, working with ethylene dibromide in the Rupert area, have determined the dosage, placement, plant tolerance and efficiency of application for sandy loam soil. The successful fumigation of 300 acres of sugar beets in 1950 and 600 acres in 1951 established the ethylene dibromide treatment as an effective commercial control for this pest.

The use of aldrin, dieldrin, or heptachlor mixed with fertilizer, applied broadcast over the soil surface, and harrowed lightly into the soil has proved successful in controlling this maggot. Treating seed before planting to prevent damage to seedlings by soil-infesting insects, such as wireworms and the seed-corn maggot, is a recent development. Seed treatment gives as good control of the sugar beet root maggot as any method tested. It should be emphasized, however, that this is a report of experimental results and does not constitute a recommendation for the use of these materials.

Summary

Experiments with several insecticides were conducted for the control of the sugar beet root maggot at Rupert, Idaho, in 1950 and 1951. The effectiveness of insecticides applied mixed with a fertilizer as a soil treatment and as a seed treatment was compared with that of a soil fumigant. Plots were four rows wide and were arranged in randomized blocks.

The most effective soil treatments were aldrin, dieldrin and heptachlor, all of which gave gains in yields of beets more than four tons per acre as compared with untreated checks.

The most effective seed treatments were aldrin at ½ pound and heptachlor at ¼ pound per 100 pounds of seed. The most effective time for fumigation with ethylene dibromide was during the egg stage of the root maggot, which resulted in an increase in yield over the check of nearly five tons per acre. The June 1 application of ethylene dibromide gave an increase in yield of beets of nearly three tons per acre over the June 12 treatment.

These experiments show that seed treatment gives as good control of this insect as any method tested.

The results of the experiments reported do not constitute a recommendation.

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Effect of DDT on Beet Leafhoppers, Curly Top, and Yields of Sugar Beet Varieties[1]

ALBERT M. MURPHY AND J. R. DOUGLASS[2]

Introduction

Since 1897, curly top, a virus disease affecting beets, beans, tomatoes, cantaloup and many garden crops, has been a disease of major economic importance in intermountain areas subject to infestation by the beet leafhopper (*Circulifer tenellus* (Bak.)), the only known agent of transmission. The geographic distribution of the disease is, therefore, the same as that of the insect, which is sporadic in its appearance; hence, the severity of curly-top injury fluctuates from year to year.

For a period of years, various investigators have conducted experiments to reduce curly top damage by controlling its vector. Romney (5)[3] was the first to show any significant reduction in curly top and increases in seed yields when the seed-beet fields were sprayed in the fall with pyrethrum-in-oil for the control of the beet leafhopper. Hills et al. (4) showed that DDT applied at dosages of from two to three pounds of toxicant per acre gave as good an initial kill as the recommended pyrethrum-in-oil spray and that the residual effect was sufficient to hold leafhopper populations at a low level for at least one to two weeks after application. Smith (6) showed that a highly refined petroleum oil containing 4.5 percent DDT spray applied at six gallons per acre gave control of the beet leafhopper for 15 days. Douglass et al. (1), working with several chlorinated hydrocarbon compounds, HEPT, and pyrethrum, found that DDT was the most effective insecticide tested against the beet leafhopper. Douglass et al. (2) showed that curly-top-susceptible R. and G. Old Type beets could be protected from curly top infection by controlling the beet leafhopper under conditions of extreme exposure. Giddings (3) showed that resistance of the sugar beet to curly top increases rapidly with the size and age of the plant.

Over a four-year period (1948-1951) the authors investigated the effect of spraying with DDT on sugar beet varieties which varied in their resistance to curly top.

Methods and Materials

To increase the curly top exposure by obtaining a high natural infestation of beet leafhoppers, the plots were located near a desert breeding area of the insect, and the planting date was delayed about five weeks from the normal planting date for the area. An attempt was made to plant the sugar beet seed each year so that the plants would be in the seedling stage, the period of greatest susceptibility, when the spring movement of the leafhoppers was expected to reach its peak. The planting dates for the four years of the experiment varied from May 18 to 29. Four sugar beet varieties of varying degrees of curly top resistance were used each year, and these varieties were selected so that at least one variety represented each of

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[3] Numbers in parentheses refer to literature cited.

the three main types of resistance, namely 1. high resistance, 2. intermediate resistance, and 3. susceptible.

Two experimental designs were used. For the first three years (1948, 1949 and 1950) the experimental area was equally divided—one-half being treated and one-half left untreated. Within the treated and untreated areas the varieties were replicated. This design, however, was not suitable to evaluate statistically the effect of treatment. Therefore, the 1951 test was enlarged and treatments were replicated as well as varieties. The experimental design, which permitted the evaluation of the effects of the spray treatments as precisely as possible, was prepared by Dr. D. D. Mason, Biometrician, B.P.I.S.A.E., taking into consideration the limitation of the size of the area, the problem of spray drift, and the activity of the beet leafhopper. The varieties and treatments were replicated eight times. This split plot design provided for eight guard rows between each of the spray treatments. The four guard rows associated with each test plot were planted to the same variety as the adjacent test plot and were sprayed or unsprayed according to the treatments of the adjacent whole plot. In other words, the area was planted as if each subplot was eight rows wide and 60 feet long and was sprayed as if each whole plot was 16 rows wide and 120 feet long.

For all years, the spray applications were begun as soon as the seedlings emerged and the treatment repeated three more times at weekly intervals, except in 1949 when five applications were made. Generally, the treatments were applied at seven-day intervals, but rains or high winds on two occasions prevented the spray schedule.

The DDT emulsion was applied with power equipment at a dosage of 1.5 pounds of toxicant per acre-application in 100 gallons of spray at about 400 pounds pressure.

The formula used for the spray treatment was 1.5 pounds of technical DDT; 1,200 milliliters of a non-volatile solvent, chiefly di-- and tri-methylnapthalenes, and 100 milliliters of a proprietary emulsifier of polyethyl aryl alcohol per 100 gallons of spray.

The effectiveness of the DDT spray material was determined by comparing pre- and post-treatment numbers of adult beet leafhoppers, by curly top counts and by yield data from the sprayed and unsprayed plots. The leafhopper counts were made with the square-foot sampler. The samples, which were taken at random along the beet rows, included more than one plant before thinning but single plants after thinning. Counts were made just before each application and seven days after the last treatment. Since counts show that better than 95 percent control of this leafhopper is obtained with a similar spray one day after treatment, the increase in population is, therefore, a result of reinfestation from incoming migrants or from redistribution over the plots after each spray application.

Experimental Results

In the 1948 and 1949 tests, difficulty was encountered with irregular beet stands as a result of wireworm injury, which made it difficult to evaluate the effect of treatment. However, yield data showed that the susceptible variety and the one of intermediate resistance made a higher yield when treated than did the untreated plots. For the highly resistant variety S. L. 72 (U. S. 22/3) in these tests, treatment had little influence on the yield. The leafhopper population in 1948 reached a peak of 212 leafhoppers per 10

Table 1.—The Effect of a DDT Spray Applied June 9, 16, 23 and 30, 1950, on Adult Beet Leafhopper Populations in Sugar Beets.

Date	Average leafhoppers per 100 square feet in plots		
	Treated	Untreated	Reduction
1950	Number	Number	Percent
June 9	74	76	.....
June 16	92	218	57.6
June 23	200	240	41.2
June 30	348	632	44.9
July 7	184	304	39.5

samples in the untreated plots, while in 1949 there were 264 leafhoppers at the peak. The leafhopper population for these two years is, therefore, quite comparable and can be regarded as of moderate intensity in relation to the tests of 1950 and 1951.

The leafhopper infestation in 1950 was the highest of any of the four years since the population reached a peak of 632 leafhoppers per 100 square feet, as shown in Table 1, while the infestation in 1951 was the lowest, reaching a peak of 144 leafhoppers per 100 square feet. The effect of four sprays of DDT applied June 9, 16, 23 and 30, 1950, on adult beet leafhopper populations is given in Table 1. There were 74 and 76 leafhoppers per 100 square-foot samples on the treated and untreated plots before the first application of DDT was applied on June 9. June 30, when the peak was reached, the number of leafhoppers increased to 348 and 632 in the treated and untreated plots. The seven-day post-treatment differences in populations between the sprayed and unsprayed plots on June 16, 23, 30 and July 7 were 126, 140, 284 and 120 adults. Table 1 also gives the percentage decrease in adult population in the sprayed and unsprayed plots.

Table 2.—A Comparison of Yield as Affected by Four Applications of a DDT Spray for the Control of the Beet Leafhopper and Curly Top in 1950.

Variety and S. L. number	Treated			Untreated		
	Beets[1]	Yield	Curly top July 10	Beets[1]	Yield	Curly top July 10
	Number	Tons	Percent	Number	Tons	Percent
U. S. 22/3 (S. L. 72)	82	19.6	1.1	79	14.8	1.9
U. S. 56/2 (S. L. 859)	84	14.0	10.1	87	10.1	17.4
R. and G. Old Type (1-300)	38	3.8	92.8	11	.6	100.0
S. L. 742	5	.3	99.2	1	.1	100.0

[1] Per 108 feet of row at harvest.

A summary of the average percent curly top on July 10 and yield per acre for the different varieties in the 1950 test is given in Table 2. The differences in yield between the treated and untreated plots were 4.8, 3.9, 3.2 and 0.2 tons per acre for varieties U. S. 22/3, U. S. 56/2, R. and G. Old Type, and S. L. 742. The variety S. L. 742 is much more susceptible to curly top than R. and G. Old Type, and the purpose of including it in at least one test was to get a better measure as to the extent of control than could be expected on the most susceptible variety available. Under the

conditions of the 1950 test, four applications of DDT did not afford this variety enough protection to make much of a showing.

In 1950 the sprayed block gave increased yields over that of the unsprayed block, but neither the difference in percent of curly top nor the difference in stand seemed to account for the large increase in yield (4.8 tons per acre) in the case of U. S. 22/3. However, the treatment effect was confounded with place effect, and it was not possible to determine whether the increase in yield was statistically significant. Since the results of the 1950 test were at variance with the similar 1948 and 1949 tests, it indicated the necessity for additional work with a different experimental design. To obtain statistical evaluation of the effect of treatment, both treatment and varieties were replicated in the 1951 test in order to separate possible soil location effects from treatment effects.

By the year 1951, a variety more resistant to curly top than S. L. 72 (U. S. 22/3) had been developed. This was the male sterile hybrid S. L. 92 H1, which represents a fourth backcross to the inbred CT9 x SL 92, a highly resistant mass selected line.

In the 1951 test there was considerable spray injury to the young seedlings. Spray injury had been noted before and in every previous instance had been followed by light rains. However, spray injury was more severe in the 1951 test than in any of the previous tests and probably depressed yields to some extent. This may help to explain why the highly resistant male sterile hybrid 92 H1 yielded 1.73 tons per acre more in the untreated plots than in the treated plots. It was difficult to evaluate the extent of spray injury as to varieties, but it is possible that 92 H1 was more susceptible to injury of this type or else recovery was slower than in the case of the other varieties. Injury consisted of burning, which produced a pitting effect on the leaves where the spray droplets had dried, and an inward rolling of the leaves. Some leaves dropped off the plants which were the most severely injured.

Table 3.—The Effect of a DDT Spray Applied June 11, 19, 25 and July 3, 1951, on Adult Beet Leafhopper Populations on Sugar Beets.

Date	Average leafhoppers per 100 square feet in plots		
	Treated	Untreated	Control
1951	Number	Number	Percent
June 11	144	132	----
June 19	22	66	66.7
June 25	24	100	76.0
July 3	18	35	48.6

The effect of DDT on the beet leafhopper in the treated and untreated plots for the 1951 test is given in Table 3. This table shows that the pretreatment population was 144 and 132 leafhoppers per 100 square-foot samples. This population decreased to 22 and 66 adults on June 19, increased to 24 and 100 on June 25, and then decreased to 18 and 35 leafhoppers on July 3 in the treated and untreated plots.

The post-treatment difference in population between the treated and untreated plots (Table 3) on June 19, 25 and July 3 and 44, 76 and 17 adults or 66.7, 76.0 and 48.6 percent.

A summary of the average percent curly top on June 30, curly top grade on October 1, and yield per acre for the different varieties in the 1951 test is given in Table 4. The data presented in the table show that there was little difference in the percentage of curly top for the two most resistant varieties on June 30 but there was a difference in favor of the treatment in the less resistant and susceptible varieties.

Table 4.—A Comparison of Curly-top Infection, Plant Stand and Yield of Sugar Beet Varieties as Affected by Four Spray Applications of DDT for the Control of the Beet Leafhopper in 1951.

Treatment	Beet varieties	Curly top June 30	Curly top October 1	Stand of beets per 100 feet of row at Thinning	Stand of beets per 100 feet of row at Harvest	Mean yield of beets per acre
		Percent	Grade	Number	Number	Tons
DDT	92 H1	1.6	0.4	92	95	18.22
Untreated	92 H1	.9	.4	102	101	19.95
DDT	S. L. 72	1.7	.8	95	92	17.01
Untreated	S. L. 72	1.8	1.0	99	89	17.29
DDT	S. L. 859	10.8	1.7	118	103	15.01
Untreated	S. L. 859	17.1	2.0	119	93	14.26
DDT	R. and G. (1-300)	87.6	3.6	104	66	8.51
Untreated	R. and G. (1-300)	97.2	4.0	97	42	4.87
Difference required for significance (19:1)						1.16
Difference required for significance (99:1)						1.54

There was practically no loss in plant stand between thinning and harvesting of the more resistant varieties of beets, but in the intermediate and susceptible varieties there was a loss. A comparison of this loss between the treated and untreated plots will show that 9.1 and 20.2 percent more plants were lost in the untreated than in the treated plots for varieties S. L. 859 and R. and G. Old Type. A study of yields of beets per acre shows that the untreated outyielded the treated plots 1.73 tons for the male sterile hybrid 92 H1, which possessed the highest degree of curly-top resistance. However, it will be noted from Table 4 that the stands were better in the untreated than in the treated plots. There was little difference in yield between the treated and untreated plots for S. L. 72. In the variety of intermediate resistance, S. L. 859, there was a gain of 0.75 tons per acre in favor of the treatment, but this increase was not great enough to be statistically significant. The treatment of susceptible variety R. and G. Old Type gave an increase in yield of 3.64 tons over the untreated plots, which was statistically significant.

The results of the 1951 spray treatment did not show an increase in the yield of the two most resistant varieties. Possibly this was because the leafhopper populations and, hence, the curly top exposure did not reach a level where the spray treatment would have shown an effect.

The 1951 experimental design, while an improvement over the other three years of the test, was not entirely satisfactory. With an insect as active as the beet leafhopper, disturbances such as cultivation, weeding, etc., cause the insect to move and when relatively small plots are used they redistribute themselves more or less over the entire experimental area. This movement of the causal agent of the disease makes the treatment less effective. However, the control of drift with respect to spray material and of insects was

relatively good. Otherwise all effects would have been equalized and the large differences between treated and untreated plots for the susceptible variety R. and G. Old Type would not have been apparent.

Summary and Conclusions

Field tests with DDT spray treatments were investigated over a four-year period for four sugar beet varieties ranging from susceptible to highly resistant. The planting date was delayed five weeks to increase the curly top exposure. Spray treatments were begun as soon as the seedlings emerged and were repeated at weekly intervals for four or five weeks.

The highest leafhopper population occurred in 1950, and the difference in yield between the treated and untreated plots was 4.8, 3.9, 3.2 and 0.2 tons per acre for varieties U. S. 22/3, U. S. 56/2, R. and G. Old Type and S. L. 742. However, because of the experimental design used in the 1950 test, it was impossible to determine whether this difference was due to treatment or to location of unreplicated plots. Under the drastic curly top exposure in the 1950 test four applications of DDT did not afford sufficient protection to the susceptible varieties to produce a commercial crop.

During years of comparatively low leafhopper populations, sprays gave gains in yield for only the susceptible varieties, since the curly top exposure was not sufficient to decrease the yields of resistant varieties. In 1951, a statistically significant gain as a result of treatment was obtained for R. and G. Old Type, which showed an increase of 3.64 tons per acre over the check.

Because of the complexity of the problem, the effectiveness of a DDT spray treatment is difficult to measure accurately, but the evidence seems to indicate that in the case of varieties intermediate in resistance some benefit can be expected under certain conditions from spraying.

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Comparative Toxicity of Some New Insecticides to the Beet Webworm in Colorado, 1951[1] [2]

J. R. Douglass and Van E. Romney[3]

The beet webworm (*Loxostege sticticalis* (L.)) is an important pest of sugar beets in the Great Plains and Rocky Mountain States. Its outbreaks are sporadic, as to both season and locality. Pepper and Hastings (1)[4] and Pepper (2) have shown that sterility is common among females of the beet webworm and that the presence of a large number of moths does not necessarily presage an outbreak of the larvae. Therefore, the degree of sterility is probably as important a factor in governing outbreaks as are favorable host plants, parasitization or weather conditions.

There are normally three generations a year. Generally, only the second generation is of economic importance, but occasionally, according to Maxson (3), both the June and the August generations may cause serious injury.

Larvae in the first three instars feed largely on the underside of the leaves, but the next two instars may feed anywhere on the aerial parts of the plants. The larvae are most vulnerable to insecticides during the first few days after hatching.

In the infested areas there has probably been more money spent in controlling the beet webworm than any other insect attacking sugar beets. For years Paris green was the standard insecticide for this purpose. Later pyrethrum was used, but because of its instability in storage, lack of availability on short notice, and high cost, a pressing need existed for other effective insecticides. Within the last few years toxaphene has been used to a slight extent, but variable results with this insecticide have been reported.

In an experiment conducted in 1949 at the Twin Falls, Idaho, laboratory of the Bureau of Entomology and Plant Quarantine, parathion was the most effective insecticide tested against the beet webworm. In 1951 two experiments for the control of this insect were conducted at Gill and Longmont, Colorado, in cooperation with the Great Western Sugar Company, the Colorado Agricultural Experiment Station, and sugar beet growers. Several organic phosphorus compounds, several chlorinated hydrocarbons and pyrethrum were included in these tests, which are reported in this paper.

Methods

The sugar beet fields selected for treatment contained high and uniform infestations of beet webworms. The plants in Field 1 were small, with leaves from 8 to 10 inches long; those in Field 2 were larger, with leaves from 15 to 18 inches long and almost closing the space between the rows. The webworms in Field 1 were principally of the first and second instars; eggs were also hatching in this field. In Field 2 most of the larvae were in the third and fourth instars.

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[2] R. T. Nelson, the Great Western Sugar Company, and Leslie B. Daniels, Colorado Agricultural Experiment Station, cooperated in these experiments. Glenn E. Critser, Bureau of Entomology and Plant Quarantine, assisted in the field work.

[3] Entomologist, U. S. Department of Agriculture, Agricultural Research Administration, Bureau of Entomology and Plant Quarantine, and Entomologist, formerly of the same Bureau, respectively.

[4] Numbers in parentheses refer to literature cited.

The randomized block method was used in setting up the experiments. Ten treatments were tested in Experiment 1 and eight treatments in Experiment 2. Each treatment was replicated four times. Check plots were used in the first experiment but not in the second. The rows were 20 inches wide in Field 1 and 22 inches wide in Field 2. Because of the difference in width, Field 1 was divided into 16-row and Field 2 into 14-row parallel plots. These plots were 440 and 600 feet long, respectively.

The following insecticides were tested:

Aldrin	Dieldrin	Metacide
Chlordane	EPN	Parathion
Compound 269	Heptachlor	Pyrethrum
Compound 711	Lindane	Toxaphene

Endrin and isodrin are stereoisomers, respectively, of dieldrin and aldrin.

All materials were applied with a mist blower equipped with a U.S.D.A. air-broadcast nozzle (Figure 1). The blower was mounted on a trailer and pulled by a tractor; a different tractor was used in each field.

The sprays were prepared from emulsifiable concentrates added to the spray tank as it was being filled with water. The spray was applied in Field 1 July 3 at the rate of 6.4 gallons per acre and in Field 2 July 5 at 5.6 gallons per acre. Windy and inclement weather prevented more experimental work in the time allocated.

The effectiveness of the materials was determined by comparing pre- and post-treatment counts of larvae per leaf. The leaf samples were taken at random from the outer leaves of the beet plants at a predetermined distance along the center four rows of each plot. Leaf samples were taken two days before treatment and again three and two days after treatment—50 samples in Experiment 1 and 30 in Experiment 2.

Table 1.—Control of the Beet Webworm with Some New Insecticides (Experiment 1).

Insecticides	Toxicant per acre	Control after 3 days
	Pounds	Percent
Toxaphene	1.94	100
EPN	.25	100
Parathion	.25	99.8
Lindane	.21	99.8
Chlordane	1.49	99.5
Heptachlor	.97	98.4
Dieldrin	.19	98
Aldrin	.37	95.5
Pyrethrum	[1]	93
Difference req. for sig. (19:1)		2.7
Difference req. for sig. (99:1)		3.7

[1] 1 quart of a preparation containing not more than 18 percent of pyrethrum extractives.

Results and Conclusions

The results of these experiments are summarized in Tables 1 and 2. Statistical analyses of the data for Experiment 1 showed no significant differ-

Table 2.—Reduction of Beet Webworms with Some New Insecticides (Experiment 2).

Materials	Toxicant per acre	Reduction after 2 days
	Pounds	Percent
Compound 269	0.25	100
Compound 711	.25	99.3
Parathion	.23	98.8
EPN	.23	98.4
Tovaphene	1.10	97.6
Metacide	.54	96.7
Dieldrin	.20	91.6
Heptachlor	1.10	90.6
Difference req. for sig. (19:1)		6.1
Difference req. for sig. (99.1)		8.3

ence in the effectiveness of toxaphene, EPN, parathion, lindane, chlordane, heptachlor and dieldrin. Aldrin and pyrethrum were less effective. On the check plots the average pretreatment population was 2.8 larvae per leaf as compared with 2.3 larvae three days later.

In Experiment 2 there was no significant difference in the effectiveness of compounds 269 and 711, parathion, EPN, toxaphene and Metacide. There was also no significant difference between Metacide and dieldrin, but Metacide was significantly superior to heptachlor.

In comparing the results of the two experiments, it should be noted that, although the larvae were in different instars and were exposed to the insecticides for different periods, there was little difference in the relative effectiveness of the insecticides.

In the second experiment a light cross-wind while the insecticides were being applied resulted in poor coverage of the three outside rows on the windward edge of the plots, so that control was not entirely satisfactory.

These experiments show that chlordane, compounds 269 and 711, EPN, lindane, Metacide, parathion and toxaphene were all very effective, with no significant differences between them. Dieldrin and heptachlor were more

Figure 1.—Mist blower used in applying the sprays.

effective against small larvae than against large larvae. Aldrin and pyrethrum were the least effective of any of the insecticides against the small larvae.

Since there is little choice between several materials on the basis of their insecticidal effectiveness, sugar beet growers in selecting and insecticide for beet webworm control should consider other factors, such as cost, availability, quickness of effect, residual effectiveness and personal safety during application. One of the important requirements is to apply the insecticide in such a manner as to obtain a complete coverage of the plants. The use of a mist blower in the experiments reported apparently had an important influence on the favorable results obtained.

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Control of the Salt Marsh Caterpillar in Sugar Beets Grown for Seed

A. A. Mast and W. B. Morrow[1]

The salt marsh caterpillar (*Estigmene acraea* Drury), first described in Europe by Drury in 1770, has been reported throughout the United States, Canada and Mexico. These caterpillars are general feeders and have been cited as injuring alfalfa, cabbage, beans, clover, potatoes, cotton, sunflowers, maize heads, guayule, asparagus, beets, turnips, lettuce, grapes, trees and ornamentals. There are also a number of weed hosts which are attractive to the larvae. Outbreaks of large populations of the salt marsh caterpillar are usually more or less localized, but cause considerable damage.

In the Salt River Valley of Arizona, the salt marsh caterpillar was first reported as affecting cotton, beans and other truck crops in 1918 (2)[2] and there have been spasmodic outbreaks since then, with one of the most serious occurring in 1951. Cotton is one of the most favorable breeding hosts and there are probably three to four generations a season developing on this crop. By late September and October, it is quite possible for populations to reach astronomical figures. The caterpillars are voracious feeders and often completely defoliate entire cotton fields. Before a cotton field is defoliated, the available food supply becomes inadequate and the caterpillars start migrating in search of a new source of food. These migrations will occur over a period of several weeks and may extend one-fourth mile or farther.

There are indications that the large buildup of populations in 1951 was due, at least in part, to the general insect control program followed by the cotton growers. Their main problems are with sucking insects, the cotton boll worm and the red spider mite. The control of these insects consists, mainly, of applications of DDT and sulphur. Occasionally, when stink bugs are present, the gamma isomer of BHC is combined with the DDT and sulphur.

The normal cotton insect control program, consisting of 15 to 20 pounds per acre of 5 percent DDT, with 40 percent sulphur, has little effect on the salt marsh caterpillar. However, it does drastically reduce their natural parasites. The resulting unchecked huge increase of the caterpillars in the cotton fields is largely due to the fact that no effort has been made to control them. The effect of the caterpillar on cotton is a moot question. Most cotton growers recognize there is a certain amount of damage due to their feeding. Their general feeling, though, is that the benefits of defoliation more than offset any injury.

Defoliation of cotton fields just before picking is desirable because the direct sunlight will open up the bolls more rapidly. Also, due to the absence of leaves, a cleaner picking job can be obtained, both by mechanical and hand picking. In early fields of cotton, this complete defoliation by the salt marsh caterpillar may more than offset the amount of injury to the

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[2] Numbers in parentheses refer to literature cited.

crop. Late fields of cotton, however, are often seriously damaged because the bolls have not reached sufficient maturity at the time defoliation occurs, resulting in reduced yields.

The logical solution in Arizona to the salt marsh caterpillar problem would be for the cotton growers to incorporate an effective insecticide, such as toxaphene, into their general insect control program and, unless this is done, salt marsh caterpillars will continue to jeopardize other crops.

Particularly vulnerable to the migrating caterpillars are such crops as newly planted sugar beets grown for seed, young alfalfa and truck crops. These crops can be completely destroyed in a matter of a very short time, and immediate control steps are mandatory. Generally, the salt marsh caterpillar is a leaf feeder; however, in the case of sugar beets, it has been observed that in heavy infestations it will consume the entire petiole and will feed well into the crown of the beet.

Chemical control is not always adequate, as there are a number of problems involved; mainly, that the migration of the caterpillars can extend over a period of several weeks, with additional larvae entering the fields each day. Early attempts to control them with arsenicals and sodium fluosilicate met with little success. These insecticides act as a stomach poison and, in the case of the salt marsh caterpillar, their action is rather slow. A crop treated with these materials may suffer considerable damage before the caterpillars have assimilated a lethal dose.

It was not until chlorinated hydrocarbons became available that there was any promise of a satisfactory insecticidal control. Dusts containing 15 to 20 percent toxaphene, or 15 percent toxaphene combined with 5 percent DDT, applied at rates of 30 to 40 pounds per acre, have proven quite effective. The 15 percent toxaphene-5 percent DDT dust may have some advantages, as it is suspected that there may be some synergistic action due to their combination.

In crops such as sugar beets grown for seed, where there is no injurious action due to its use, three pounds of toxaphene in an emulsifiable oil, with 30 to 40 gallons of water per acre, will probably give the most efficient control. However, as mentioned earlier, since migrations of this pest occur over a considerable period of time, none of the above mentioned chemical controls has sufficient residual action for one application to give complete control and the cost of additional treatments makes them prohibitive. Therefore, insecticidal control alone is not adequate in controlling heavy migrations over a long period; however, a small migration, occurring over a short time, can be economically controlled by use of insecticides.

For many years, attempts have been made to stop the migration of the salt marsh caterpillars by the use of barriers around the fields. Chemical barriers made by placing bands of insecticides, containing toxaphene and BHC, through which the migrating caterpillars would have to crawl, have been ineffective. The first attempts at the use of mechanical barriers consisted of a furrow or a ditch, which were relatively ineffective. The next step was to fill the ditches with water. Two types of water barriers are often used—the most effective one being the use of running water, rather

than stagnant water. Even on ditches where running water is utilized, during heavy migrations, it is often advisable to have diesel fuel oil drip into the water. Although quite effective, a water barrier is often difficult to install and, in many cases, it is not possible to divert enough water into these ditches.

During the last two years, aluminum foil has been used as a barrier against migrating caterpillars with considerable success. The idea of using aluminum foil was first conceived at Salinas, California, in 1949, by J. Mandeen, general sales manager of Growers Aluminum Supply Company. Through his efforts, a suitable grade of aluminum foil is now on the market.

This aluminum foil is .0015 inch in thickness, 7 inches wide, and comes in rolls approximately ⅜ of a mile in length. It is embedded vertically into the soil, with 2 to 3 inches under ground, leaving 4 to 5 inches above ground. The surface of the foil is very smooth and migrating caterpillars are unable to crawl over it and, therefore, collect in large numbers in front of the barrier. Since they are unable to proceed forward, they travel in both directions parallel to the foil. To relieve this situation, holes two to three feet deep are dug in front of the barrier. These holes trap the caterpillars and prevent them from building up along the foil barrier in such numbers as to become high enough to form a bridge over it into the field. When these holes become completely filled, they are covered with dirt and new ones dug.

During the 1951 season, aluminum foil became very short in supply and it was necessary to turn to substitute materials which would be effective in stopping the migrating larvae. Several types of waxed paper were used and were found to be quite effective for a short period of time. However, waxed paper was especially vulnerable to winds and rain; consequently, such a barrier was very difficult to maintain and, generally, was found unsatisfactory for these reasons.

When aluminum foil was practically unobtainable, members of the staff of Western Seed Production Corporation, with the cooperation of Reynolds Metals Company, tested some products used in the building trades as experimental barriers. One type of roofing material, consisting of aluminum foil embossed on tar paper, was found to be equally as effective as the straight aluminum foil and had several other rather distinct advantages, such as properties of rigidity, which simplified the erection of the barrier and, also, due to generally heavier construction, enabled it to withstand very high winds and rain, with a minimum of maintenance. This material has been sold under the trade name of Kool-rey. Reynolds Metal Company have preliminary plans whereby this material will be available in another year in 500-foot lengths, cut 6½ inches in width.

The aluminum foil barrier is a very efficient method of controlling the salt marsh caterpillar and, at present price levels, the cost of the foil is approximately one cent per lineal foot. Three men should be able to set up one mile of barrier per day or the equivalent of a barrier surrounding a 40-acre field. Such a barrier will cost only about one-third as much as one dust application and is much more effective.

The ideal control program combines the use of both efficient barriers

and insecticides. Barriers are seldom installed until a considerable number of caterpillars have already migrated, and a few will invariably get over any barrier. These can easily be eliminated by the application of insecticides around the border of the field immediately after installation of the barrier. Such a program will keep damage to an absolute minimum and protect the crop for the duration of the migration.

Summary

When small migrations of caterpillars occur over a rather short period, insecticidal control is probably adequate.

Where large scale migrations extend over a considerable period of time, barriers are a necessity. The aluminum foil and the foil-embossed roofing material barriers are cheaper and, generally, more satisfactory than the water barrier. However, in the use of any type of barrier, it is often necessary to resort to some insecticidal control because, in many instances, there are already some caterpillars in the fields to be protected. Also, with any barrier, a few caterpillars will make their way into the field.

Where insecticidal control is needed, dusts containing 15 to 20 percent toxaphene, or 15 percent toxaphene with 5 percent DDT, applied at the rate of 30 to 40 pounds per acre, will give adequate control. A spray containing three pounds of toxaphene in an emulsifiable oil, at the rate of 30 to 40 gallons of water per acre, will assure equal or better results.

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Effects of Crop Rotation on the Incidence of Root-Knot Disease of Sugar Beets in Western Nebraska[1]

M. L. Schuster and Lionel Harris[2]

Introduction

The irrigated rotation experiments at the Scotts Bluff Substation, Mitchell, Nebraska, lend themselves to a study of the effects of crop sequence, fertilization and length of rotations on the incidence of root-knot caused by *Meloidogyne* spp. The disease is of economic importance on sugar beets in the sandier soils of western Nebraska. This area approximates the territory north of the North Platte River and includes portions of Scotts Bluff, Sioux and Morrill Counties. The Tripp very fine sandy soil on the Field Station is representative of much of this area. It is agreed that root knot is essentially a disease of sandy soils (7, 12, 18),[3] but severe infections sometimes occur on clay soils (18).

Bessey (2), Godfrey (7), Shaw (16), Tyler (18), and others have reported rotation of crops as a means of decreasing the severity of the nematode disease. Atkinson (1) and Neal (11) have reported conflicting evidence as to behavior and range of hosts of the root-knot nematode, *Heterodora marioni* (Cornu) Goodey. Christie and associates (4, 5, 6) have determined that the species consist of several diverse kinds of nematodes. Chitwood (3) in 1949 has found *Heterodora marioni* to be comprised of at least five different species which have been separated from the genus *Heterodora* and placed in the genus *Meloidogyne* Goeldi, 1887.

Observations in 1947 and later indicated that the host range of the root-knot nematode in western Nebraska was narrower than previously reported (15). The determination of effects of crop rotation on root knot of sugar beets in western Nebraska was considered expedient because of previous host range studies. Data from crop rotation experiments are incorporated in this paper.

Materials and Methods

The rotations selected for this study were located at the Scotts Bluff Substation, Mitchell, Nebraska, (Field K). These rotations were inaugurated in 1912 dealing with various methods of utilizing irrigated land and were carried out as originally planned from 1912 to 1941.

The new rotation program inaugurated in 1942 and continued to 1949 included: studies of the value of farm manure, mineral fertilizer including chiefly treble superphosphate and ammonium sulfate, alfalfa as green manure, and sweet clover as a pasture and green manure crop when used in the various types of cropping practices. In this new program, barley replaced oats in rotations where a small grain crop was involved. Other principal crops included were alfalfa, sugar beets, potatoes and beans. The crop

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[3] Numbers in parentheses refer to literature cited.

Table 1.—New Rotation Numbers, Crop Sequences, Fertilization and Length of Sugar Beet Rotations at the Scotts Bluff Substation, Mitchell, Nebraska.

New Rotation No.	Crop Sequence and Fertilization[1]	Length of Rotation
2	beets	continuous
2D	beets (NP)	continuous
20	beets, potatoes	2
20C	beets (NP^2), potatoes (NP^2)	2
21	beets (M), potatoes	2
33	beets, barley-sweet clover, potatoes	3
33B	beets (M), barley-sweet clover, potatoes	3
35	beets, barley, potatoes	3
35B	beets (M), barley, potatoes	3
35C	beets (NP^2), barley, potatoes (NP^2)	3
41	beets, barley-alfalfa, alfalfa, potatoes	4
41B	beets (M), barley-alfalfa, alfalfa, potatoes	4
41C	beets (NP), barley-alfalfa, alfalfa, potatoes (P)	4
43B	beets (M), barley, beans, potatoes	4
43C	beets (NP^2), barley, beans, potatoes (NP^2)	4
49	beets, barley-sweet clover, sweet clover pasture, potatoes	4
49C	beets (NP) barley-sweet clover, sweet clover pasture, potatoes	4
49D	beets (NP) barley-sweet clover, sweet clover cut, potatoes (P)	4
63	beets, barley-alfalfa, alfalfa (3 yrs.), potatoes	6
63B	beets (M), barley-alfalfa, alfalfa (3 yrs.), potatoes	6
63C	beets (NP), barley-alfalfa, alfalfa (3 yrs.), potatoes (P)	6
66B	beets (M), barley-alfalfa, alfalfa (2 yrs.), potatoes, beans	6
66C	beets (NP), barley-alfalfa, alfalfa (2 yrs.), potatoes (P), beans	6

[1] (M)—farm manure applied at the rate of 12 tons per acre.
(NP)—102 pounds of nitrogen and 56 pounds of P_2O_5 per acre.
(NP^2)—51 pounds of nitrogen and 56 pounds of P_2O_5 per acre.
(P)—56 pounds of P_2O_5 per acre.
Previous to 1945, the application of nitrogen amounted to 26 pounds per acre.

rotations comprise, in addition to continuous plots, rotations varying in length from 2 to 6 years (Table 1).

Observations in 1933 and 1934 were made on 15 rotation types in Field K. About 100 sugar beets from each plot were selected at random, dug manually and roots examined. During the four-year period from 1946 to 1949 the different types of crop rotations selected totaled 22. The roots were examined after the beets were pulled mechanically and topped. The number of beets selected at random ranged from 42 to 366 per plot; this variation in number was due in part to the number of plants which survived as a result of various causes. The plants were dug at the regular harvest date, usually during the latter part of October.

Observational ratings were employed in classifying the material. An accurate determination of the degree of infection could have been obtained by counting of number of galls per beet except that large numbers of roots examined made gall counts impractical; also, many roots were broken off during digging operations. It was found that each plot could be conveniently classified into one of four categories with respect to severity or absence of infection.

Infection categories described are as follows: 0 = No sign of infection, as evidenced by the absence of any galls on the main or secondary roots; 1 = Slight infection, as evidenced by the presence of small and few galls

on the secondary roots; 2 = Moderate infection, as evidenced by the presence of larger and more galls on the secondary roots and occasional galls on the main root; 3 = Abundant infection, as evidenced by numerous large galls on the main and secondary roots with coalescing of galls a common occurrence. It was believed that this method was satisfactory and practical in the comparative determinations of amount of root knot in the experimental plots.

Table 2.—Prevalence of Root-Knot Nematode in Sugar Beets in the Irrigated Rotation Experiments 22 and 23 Years After the Rotations Were Started. Scotts Bluff Substation.

Rotation number	Crop sequence and treatment[1]	Percent of beets with galls 1933	1934
2	beets	43	22
20	beets, potatoes	31	16
21	beets (M), potatoes	27	00
22	beets, oats	35	00
18	beets, wheat	56	28
32	beets, corn, oats	43	14
35	beets, potatoes, oats	44	18
35B	beets, potatoes, oats	27	7
45—1st yr.	barley—sweet clover, sweet clover pasture, beets (1), beets (2)	00	00
—2nd yr.	barley-sweet clover, sweet clover pasture, beets (1), beets (2)	00	00
41	beets, alfalfa, alfalfa, potatoes	00	00
42	beets, alfalfa, alfalfa, oats	00	01
63	beets, alfalfa (3 yrs.), potatoes, oats	00	00
63B	beets, alfalfa (3 yrs.), potatoes, oats (M)	00	00
62	beets, alfalfa (3 yrs.), corn, oats	00	00
64	beets, oats-alfalfa, alfalfa (2 yrs.), potatoes	00	4

[1](M)—refers to application of 12 tons farm manure per acre.

A disease index method appeared satisfactory in comparative determination of the amount of disease in the experimental plots. It is as follows:

$$\text{Disease index} = \frac{\Sigma \text{ Category numbers} \quad \times 100}{\text{Total No. of plants} \times 3}$$

The 3 in the denominator represents maximum infection and 100 is used to convert to percentage. The summarization of category numbers is obtained by multiplying the number of plants in each category by their respective category numbers from 0 to 3, and adding the products. The result is the comparative infection rating for the rotation plots.

Results

The information on the percentage of diseased beets in the rotations in 1933 and 1934, or 22 and 23 years after the rotations were established, is shown in Table 2. Root knot was present in the two-year and three-year rotations at this time, but was not observed in beets grown in rotations four years or six years in length. The production of sweet clover or alfalfa as legumes in the four-year and six-year rotatoins and the increase in length of rotation effected by growing these legume crops appeared to effectively control the root knot up to this time. For example, rotation 20 may be compared directly with rotation 41. These rotations are the same except that rotation 41 has two years of alfalfa. In 1933, 31 percent of the beet

roots from rotation 20 were affected with root knot and in 1934 16 percent were affected, compared with the absence of the disease in beets from rotation 41. Rotations 22 and 42 may be compared in a similar manner. Direct comparisons of the three-year rotations with the six-year rotations may be made as follows: rotation 35 and 63; rotation 35B with 63B, and rotation 32 and 62. In each instance the increase in length of the rotation and the presence of alfalfa appeared to eliminate the root-knot disease in sugar beets.

Crop rotation is probably the most important single method of control of root knot (2, 7, 16, 18). The studies as entered in Table 3 indicate that length of rotation had a definite effect on root knot of sugar beets. The average disease index values for the four-year period for the unfertilized plots in rotations 2, 20, 33, 35, 41, 49 and 63 were 82, 94, 34, 31, 33, 37 and 24 percent, respectively. This trend was evident for each of the four years 1946, 1947, 1948 and 1949. A similar tendency was noted for the comparable fertilized plots.

Ludecke (10) and others found that nutrition affects the amount of root knot. Oteifa (13) reported that potassium affects reproduction rate of *Meloidogyne incognita*. A potassium fertilizer was reported as helpful in protecting plants from nematode injury (18). In the four-year study, application of farm manure or commercial fertilizer did not consistently alter the severity of root-knot in all types of rotations. A decrease resulted in the continuous sugar beet plot (No. 2D) with application of commercial fertilization. Farm manure and commercial fertilizer decreased the disease in the two-year rotations. Some beneficial effects due to fertilization appeared in the four-year rotations in which sweet clover was employed as a legume (Nos. 49C, 49D); this was not the case in the other four-year rotations or in the three- or six-year rotations.

The effect of different crops in a sequence on root knot seemed probable. As shown in Table 3, no apparent differences were manifest in the three-year rotations in which barley (No. 35) was used in lieu of the barley-sweet clover combination (No. 33). No marked difference resulted where sweet clover was substituted for alfalfa. Either legume may be effective in decreasing root knot as King (8) reported that alfalfa is an effective and practical control of root-knot nematode of cotton. Although a new rotation program was inaugurated in 1942, some of the six-year rotations are directly comparable from 1912 to 1949. Such is the case with rotations 63 and 63B in which barley was substituted for oats and the sequence was changed, but was similar for both rotations. Rotation 63B had less disease than 63 during the four-year period with about 50 percent less in amount in 1948. Rotation 63C showed less disease than 63 of these two above rotations, which may be due to fewer amounts of beets in the history of this rotation, beets being started in 1937; the difference may also be due to artificial fertilization.

Since there is no rotation comparable to Rotation 66B and 66C without manure or artificial fertilizer applications it is difficult to determine whether the decrease of root knot was due to manurial or artificial fertilization on the particular rotation or to some other factors. Rotation 66C.

Table 3.—Effects of Crop Sequence, Fertilization and Length of Rotations on the Infection of Sugar Beets with *Meloidogyne* sp. at Scotts Bluff Substation, Mitchell, Nebraska, for the Period 1946-1949.

Rotation number[1]	Disease Index				
	1946	1947	1948	1949	4-year ave.
2	53.97	100.00	100.00	73.68	81.91
2D	51.51	100.00	89.90	51.56	73.24
20	80.89	100.00	98.53	98.00	94.36
20C	25.33	37.48	44.67	22.22	32.43
21	43.83	56.84	61.85	59.06	55.40
33	23.74	30.39	57.67	23.19	33.75
33B	55.01	31.45	62.42	65.01	53.47
35	18.67	12.08	40.67	52.70	31.03
35B	21.67	40.11	15.00	50.00	31.70
35C	19.51	29.97	53.09	18.12	30.17
41	11.90	39.16	56.00	26.19	33.32
41B	10.34	9.74	56.90	10.62	21.92
41C	14.60	53.84	52.46	27.52	37.11
43B	12.82	35.97	37.33	5.77	22.97
43C	9.52	2.42	34.00	31.30	19.31
49	20.34	33.45	38.94	55.46	37.05
49C	22.34	17.18	13.75	18.64	17.97
49D	22.91	6.48	13.01	16.11	14.60
63	20.83	23.58	23.33	28.81	24.14
63B	20.67	19.38	12.33	26.13	19.63
63C	16.13	17.30	25.12	9.70	17.06
66B	19.00	11.06	14.81	7.08	12.99
66C	14.21	12.99	24.62	28.40	20.06

[1] See Table 1 for description of rotations.

which had a definite background of alfalfa and beets since 1912, did exhibit less root knot than rotation 63. Rotation 66 B, which is directly comparable to 66C from 1942 to 1949, showed the least amount of root knot for the 1946-1949 period. In 66B beets were first included in 1936; this and the fact that the soil was maintained at a high nitrogen level may account for the decrease in the nematode disease.

Discussion

One of the most common recommendations for the control of root knot is crop rotation. The most promising method is that of growing crops which are not susceptible to root knot until the nematodes are starved out. Even this rotation program may be replete with many difficulties in the irrigated areas of western Nebraska.

The crops planted in the rotation systems must be free from nematode attack, so that the larvae in the soil may not obtain nourishment for survival and development. The main crops in this area are sugar beets, field beans, potatoes, alfalfa, sweet clover, corn and barley.

Fortunately, field beans, potatoes, corn and barley are not susceptible to the root-knot nematodes in western Nebraska. Alfalfa and sweet clover were slightly susceptible, and may aid the nematode in surviving. Similarly many weeds, such as pigweed, lambs quarters, fireweed, blue lettuce and foxtail would also be important in this respect. Weeds are very important in the irrigated areas in cultivated fields, and along irrigation canals.

The length of rotations was one of the major factors in controlling root-knot. Sugar beet monoculture and two-year rotations apparently were very favorable for nematode survival and development. After 22 and 23 years of operation of the rotations root knot was present in beets from the two- and three-year rotations but was absent in the four- and six-year rotations. But 35 years after the establishment of the rotations, the disease was present in beets from the four- and six-year rotations also, although to a lesser extent than in the shorter rotations. It appeared that the main crop grown in the rotations which favored the survival of the nematode was sugar beets.

Heavy fertilization is recommended in connection with root knot control possibly because a well nourished plant is more able to form new roots and thereby replace those invaded by the nematodes (10, 17). Fertilization gave beneficial results in certain irrigated rotations in reducing the disease in western Nebraska. Application of commercial fertilizer (NP) and manure caused a marked decrease in the incidence of root knot, particularly in the shorter rotations. In the two-year rotations commercial fertilizer and manure markedly reduced the severity of the disease. The application of commercial fertilizer (nitrogen and phosphorus fertilizer applied in amounts approximately equivalent to the nitrogen and phosphorus applied as a manure in the two comparable two-year rotations) compared with manure applications caused a greater reduction in disease. Similar beneficial results were obtained in total tonnage of roots and total sugar production (14). In the three-year rotaions which did not contain a legume, no marked differences resulted in amount of root knot as compared to the rotations where a legume was included, providing manure or artificial fertilizer was applied. This is not in accordance with sugar yields obtained in such rotations in the same area (14). In the longer rotations the fertility status of the soil was at a high level. This may be a partial explanation for less response to any particular fertilization practice in these longer rotations as compared to the short rotations.

Elements which were studied previously in these rotations and which may affect root knot in the fertilization practices are nitrogen, phosphorus and potassium (9, 14). The first two elements have been shown to be increased in the soil by the employment of manure, commercial fertilization, or legume, or a combination of a legume with either of the other two (9, 14). The increase of these two elements in the soil could be associated with a decrease in disease as evidenced in the continuous and two-year rotations. According to Rhoades and Harris (14) and Kubota, Rhoades, and Harris (9) the inclusion of a legume in a rotation at the Scotts Bluff Substation caused a decrease in the exchangeable potassium; the non-legume rotations did not cause a decrease of this element, whereas manure application increased the exchangeable potassium content of the soil. It is possible that the increase in potassium content of the soil due to manurial applications may decrease root knot (18). The decrease in exchangeable potassium due to the inclusion of a legume in a rotation may not have been instrumental in affecting the disease since it was not lowered to a level to be critical for sugar beet production. Apparently

alfalfa in a rotation affects the disease from another standpoint other than potassium content of the soil as King (8) indicated this legume is an effective control for root knot of cotton when used in a rotation.

Summary

A study of the effects of crop rotations on root knot of sugar beets was conducted at the Scotts Bluff Substation, Michell, Nebraska. Besides continuous cropping, four different lengths of rotations were involved as well as various fertilization and cropping practices.

A root-knot index, which was employed to designate the amount of disease, indicated a consistent tendency for an increase in disease with a decrease in length of rotation. The severity of disease decreased sharply after the continuous and two-year rotations, although a few cases of abundant disease appeared in the three- and four-year rotations. Root knot was common in the short rotations 22 years after inauguration of the rotations, but was also present in the larger rotations 35 years after the program was started although to a lesser extent.

Fertilization applications decreased root knot in the short rotations. Farm manure decreased the amount of disease in the two-year rotations and commercial fertilizer consisting of nitrogen and phosphorus caused a decrease in the disease in the continuous and two-year rotations, and four-year rotations in which sweet clover was employed as a legume. No such marked beneficial effects were apparent in the other four- and six-year rotations.

There were no marked differences in root knot due to crop sequence in the rotations compared.

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Host Range of the Root-Knot Nematode of Western Nebraska[1]

M. L. SCHUSTER[2]

Introduction

Observations of the reaction of plants to the root-knot nematode of western Nebraska indicated a narrower host range than previously reported in other areas. Neal (8)[3], Atkinson (1) and others (2, 10, 14) reported conflicting evidence on the reaction of plants to this pathogen. Tyler (14) recorded an extensive list of plants and their reaction to the nematode. Since then additional hosts have been found, making a total of about 1,800 species.

The root-knot nematode appeared to vary in its pathogenicity in different parts of the United States. Recent workers (4, 5, 6, 10) considered the possibility of races of the nematode. In 1949 Chitwood (3) transferred the root-knot nematode from *Heterodora marioni* to the genus *Meloidogyne* Goeldi, 1887 and set up five species and one variety based mainly on morphological characters.

The purpose of this investigation was to determine the host range of the root-knot nematode especially of economic plants grown in irrigated rotations in western Nebraska. This information would be of interest in considering the feasibility of crop rotations as now practiced and of the advisability of using other crops which may be introduced, such as safflower. This study was conducted in the field from 1948 to 1951 (11). Included in these tests were 62 species and varieties of plants.

Materials and Methods

During the early part of the studies, a plot in the Great Western Sugar Company Farm, Mitchell, Nebraska, was employed because it was heavily infested with the root-knot organism; later tests were made on heavily infested soil at the Scotts Bluff Substation, Mitchell, Nebraska. Three replications of each variety or species were employed using a randomized block. Each replication was five feet in length. The seed was sown at the time recommended for the crop in the area. Plants were harvested and roots examined when they reached nearly full size. For example, peas were examined about six weeks and sugar beets 24 weeks after planting.

Species and varieties from 14 families of plants were tested during the period. One species or variety was tested from Liliaceae, Zygophyllaceae, Convolvulaceae, Polemoniaceae, Amaranthaceae; two from Euphorbiaceae; three from Solanaceae; four from Cucurbitaceae, Umbelliferae, Cruciferae; six from Chenopodiaceae; nine from Leguminosae; twelve from Compositae; thirteen from Gramineae. This host range included weeds which were permitted to flourish in the test plots. The susceptible sugar beet was planted in many locations in the test plots as a check or indicator plant to determine the distribution of the nematode.

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Table 1.—Host Range of the Root-knot Nematode of Western Nebraska.

Host Plant	Infection No. plants[1]	Infection Severity
Amaranthaceae		
Pigweed, *Amaranthus retroflexus* L.	3/20	slight
Chenopodiaceae, Goosefoot Family		
Lambs quarters, *Chenopodium album* L.	2/16	slight
Fireweed, *Kochia scoparia* (L.) Schrod.	2/17	severe
Sugar beet, *Beta vulgaris* L. var. G.W. 304	124/127	severe
Sugar beet, *Beta vulgaris* L. var. G.W. 526	121/135	severe
Red beet, *Beta vulgaris* L. var. Detroit Dark Red	37/44	severe
Red beet, *Beta vulgaris* L. var. Early Blood Turnip	9/9	severe
Compositae, Sunflower Family		
Lettuce, *Lactuca sativa* L. var. Grand Rapids	47/47	moderate
Lettuce, *Lactuca sativa* L. var. Black-seeded	60/60	severe
Lettuce, *Lactuca sativa* L. var. Improved Hansen Head	44/44	moderate
Blue Lettuce, *Lactuca puchella* (Purch.) DC.	2/2	severe
Sunflower, *Helianthus annuus* L.	2/8	slight
Safflower, *Carthamus tinctorious* L. var. Nebraska-8	16/20	slight
Safflower, *Carthamus tinctorious* L. var. Nebraska-852	13/37	moderate
Zinnia, *Zinnia elegans* L. var. Little Red Riding Hood	3/9	slight
Cocklebur, *Xanthium commune* Briton	4/15	slight
Bachelor buttons, *Centaurea cyanus* L. var. Jubilee Gem	2/2	slight
Great ragweed, *Ambrosia trifida* L.	0/5	none
Marigold, *Tagetes erecta* var. Chrysanthemum Flowered Hybrids	0/12	none
Convolvulaceae, Morning Glory Family		
Morning glory, *Ipomaea purpurea* (L.) Roth. var. Pearly Gates	0/4	none
Cruciferae, Mustard Family		
Radish, *Raphanus sativus* L. var. Early Scarlet Turnip	134/236	moderate
Rutabaga, *Brassica napobrassica* Mill. var. American Purple Top	35/35	severe
Brussel Sprouts, *Brassica oleracea gemmifera* Zenker var. Long Island	4/4	moderate
Turnip, *Brassica rapa* L. var. Purple Top White Globe	52/63	severe
Cucurbitaceae, Gourd Family		
Muskmelon, *Cucumis melo* L. var. Netted Gem	0/8	none
Squash, *Cucurbita maxima* Duch. var. Toble Queen	0/38	none
Pumpkin, *Cucurbita pepo* L. var. New England Pie	0/11	none
Cucumber, *Cucumis sativus* L. var. Improved Long Green	11/38	slight
Euphorbiaceae, Spurge Family		
Spotted spurge, *Chamaesyce maculata* (L.) Small	0/4	none
Castor Bean, *Ricinus communis* L. mixed vars.	1/21	slight
Gramineae, Grass Family		
Sorghum, *Sorghum vulgare* L. var. Black Hull	0/33	none
Sorghum, *Sorghum vulgare* L. var. Leoti Red	0/106	none
Sorghum, *Sorghum vulgare* L. var. Cheyenne	0/32	none
Wheat, *Triticum vulgare* L. var. Cheyenne	0/32	none
Witchgrass, *Panicum capillare*, L.	0/24	none
Field Corn, *Zea mays* L. var. Iowa 4316	0/77	none
Sweet Corn, *Zea mays* L. var. Extra Early Golden Bantam	0/27	none
Smooth brome, *Bromus inermis* L. var. Lincoln	0/18	none
Yellow foxtail, *Setaria lutescens* L.	6/27	slight
Sandbur, *Cenchrus pauciflorus* Benth.	0/5	none
Barnyard grass, *Echinocloa crus-galli* (L.) Beauv.	0/6	none
Barley, *Hordeum vulgare* L. var. Velvon 11	0/155	none
Oats, *Avena sativa* L.	0/11	none

Leguminosae, Pea Family		
Pea, *Pisum sativum* L. var. Alaska	3/57	slight
Pea, *Pisum sativum* L. var. Thomas Laxton	5/24	slight
Pea, *Pisum sativum* L. var. Stratagem	1/4	slight
Field bean, *Phaseolus vulgaris* L. var. Great Northern 123	0/45	none
Wax bean, *Phaseolus vulgaris* L. var. Startler	0/21	none
Sweet pea, *Lathyrus odoratus* L. var. Cuthbertsons mixed	0/4	none
Sweet pea, *Lathyrus odoratus* L. var. Spencer Yellow Medal	4/9	slight
Alfalfa, *Medicago sativa media* L. var. Ranger	9/51	slight
Sweet clover, *Melilotus officinalis* L. (Lamb) var. Griswold Co.	17/87	slight
Liliaceae, Lily Family		
Onion, *Allium cepa* L. var. Sweet Spanish	3/50	moderate
Polemoniaceae, Phlox Family		
Phlox, *Phlox* sp.	2/3	slight
Solanaceae, Nightshade Family		
Potato, *Solanum tuberosum* L. var. Bliss Triumph	1/25	none
Tomato, *Lycopersicum esculentum* L. var. Bonny Best	1/9	slight
Black Nightshade, *Solanum nigrum* L.	0/2	none
Umbelliferae, Parsley Family		
Carrot, *Daucus carota* L. var. Danvers One-half Long	73/73	severe
Carrot, *Daucus carota* L. var. Nantes	58/60	severe
Parsley, *Petroselinum hortense* Hoffm. var. Dark Moss Curled	20/22	severe
Parsnip, *Pastinaca sativa* L. var. Improved Hollow Crown	41/45	moderate
Zygophyllaceae, Caltrop Family		
Puncture Vine, *Tribulus terrestris* L.	2/2	slight

[1] Numerator, number of plants with galls on roots; Denominator, total number of plants examined.

The infection types were grouped into four classes based on the percentage of plants infected and the severity of disease. These classes were as follows: Healthy, no sign of infection as evidenced by the absence of galls on the roots; slight infection, by the presence of small and few galls on the secondary roots; moderate infection, the presence of larger and more galls on the secondary roots and the main root; severe infection, numerous large galls on the main and secondary roots with coalescing of galls a common occurrence. This method proved satisfactory in comparative determination of the relative susceptibility of the plants to the pathogen.

Results

The data entered in Table 1 confirm or add to the confusion of the host range which was reviewed by Tyler (14) and who cited conflicting observations and evidence from different parts of the United States. In western Nebraska the white field bean, Great Northern No. 123, appeared to be resistant. Although beans are considered by some workers (2, 15) to be susceptible to the root-knot nematods, others (14) have reported that some varieties such as Alabama No. 1 and No. 2 are resistant. The bean in western Nebraska was grown during the hotter part of the season so temperature should not be a factor (18). It was also found that the potato variety, Bliss Triumph, which is generally considered very susceptible, was free of morphological symptoms in our test. Cunningham (7) on the other hand reported this potato variety to be moderately resistant. using tuber symptoms as the criteria. Contrary to the results of other investigators (2, 15) our findings seem to indicate that certain varieties of safflower, Nebraska-8 and Nebraska-852, are susceptible to the attack of the nematode.

The data confirmed the general consensus of opinion that certain members of the Cruciferae such as turnips, rutabages, radish and Brussel sprouts

are susceptible. Confirmation was also found in regard to susceptibility of carrots, sugar beets, lettuce, onion, phlox and parsnip. Some crops slightly susceptible to root-knot nematode included Zinnia, peas, alfalfa, sweet clover, sweet peas and castor beans.

Resistance was generally found for members of the Gramineae, particularly the economic crops such as corn, wheat, sorghum, smooth brome, barley and oats. Marigold was also found to be resistant.

The Cucurbitaceae usually considered susceptible were shown to be only slightly infected, using representative species such as muskmelon, cucumber, squash and pumpkin.

Discussion

Data obtained in this study support the observations of others (3, 4, 5, 6, 10) of the variation in reaction of hosts to the root-knot nematode. There may be several reasons to account for these differences.

Many observations and records were made on the reaction of plant species to nematodes without consideration of varieties or strains of the hosts. Just as there are strains of pathogens so there may be strains of host plants. Wherever possible an attempt was made to employ named varieties in the studies reported in Table 1. Weeds, of course, were identified as to species whenever possible. Even different reactions of weeds in various parts of the country may be explained on the basis of variation within weed species.

Another explanation for divergent results may be physiological races of the nematode. One adapted to the latitude and temperatures of western Nebraska may develop at lower temperatures than a race from southern United States. Chitwood (3), Sherbakoff (10) and Christie and associates (4, 5, 6) have shown that *Heterodora marioni* can be considered as several species or races based on morphology or pathogenicity. Recently Tarjan (12) and Sasser (9) attempted to differentiate the five species of the genus *Meloidogyne* as proposed by Chitwood who used host range as a major criterion. Tarjan (12), who indicated that there were decided differences in response of snapdragons to infection by different species of the root-knot nematodes, did not arrive at any definite conclusion in this respect. Sasser (9) believed that it would be possible to differentiate these species; he used 25 plant species to decide the issue involved. He did not consider the possibility of strains within the Meloidogyne species as eventually confounding the issue.

The results obtained indicate that the irrigated rotations in western Nebraska were not in danger from the root-knot disease in so far as infection on two main crops—potatoes and field beans—were concerned. Sugar beets, however, were very susceptible and nematodes could be an important factor in production of this crop in this area, depending upon the length of rotations employed.

Summary

Sixty-two species of plants were tested under field conditions to determine their reaction to the root-knot nematode in western Nebraska. The plants were tested in fields highly infested with the nematode. They were

classified as healthy, slight, moderate, or severely infected on the basis of size and number of galls on the roots.

The field bean and potato, which are two main crops in irrigated rotations in western Nebraska and usually considered as susceptible, did not exhibit root-knot symptoms. The same was true for marigold, ragweed, morning glory and members of the Grass family.

Members of the Mustard family proved to be susceptible. Others included in this category were the carrot, safflower, sugar beet, lettuce, fireweed, onion, phlox, blue lettuce, parsnip and parsley.

Members of the Gourd family usually considered susceptible were at most only slightly susceptible. Similar data were noted for Zinnia, peas, alfalfa, sweet peas, sweet clover, castor beans, pigweed, lambs quarters, sunflower, sandbur, Bachelor buttons, yellow foxtail, tomato and puncture vine.

Crops such as potatoes, beans and corn are not susceptible to root-knot nematode; the use of these crops in sugar beet rotations should make it possible to reduce the damage from this disease. The use of non-susceptible crops will not be effective in controlling the disease if susceptible weed hosts are allowed to grow in these crops.

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Some Host and Vector Relationships of the Curly-Top Virus

N. J. GIDDINGS[1]

General Considerations)

The disease known as curly-top (Figure 1), as it occurs in North America is due to the virus *Ruga verrucosans* (Carsner and Bennett). It is known only in the western portion of the continental United States and is confined principally to the area west of the Rocky Mountains. There is only one known vector, *Circulifer tenellus* (Baker). The virus has been occasionally transmitted experimentally from one plant to another in the greenhouse by dodder, *Cuscuta* sp., and rarely by means of puncture inoculations. It is, of course, readily transmitted by grafting but not by any of the usual contact or rubbing methods. The host plant range of the virus covers at least 25 families including such diverse economic crops as beets (Chenopodiaceae), tomatoes (Solanaceae), melons (Cucurbitaceae), beans (Leguminosae), flax (Linaceae), celery (Umbelliferae and buckwheat (Polygonaceae).

Figure 1. Sugar beet plants of SL 842 variety six weeks of age. Plants at left were inoculated with curly-top virus strain 3 when two weeks old. Pot at right has plant infected with virus strain 5 and healthy control.

Curly-top diseases have been reported from Argentina (1)[2] and from Brazil (2) but the vectors are different from that of North American curly-top and the host ranges are not the same. Oman reported (3) that a study of leafhoppers in two collections showed that *C. tenellus* existed in the Mediterranean area but in his book (4), a year later, he says, "The genus

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[2] Numbers in parentheses refer to literature cited.

Circulifer is primarily an Old World group centering around the Mediterranean region" and then, "In North America the single species *tenellus* (Baker), commonly referred to as the genus Eutettix, is known to occur in Florida and certain of the West Indies, in addition to its wide range in western North America." There has been no report of plants infected with curly-top in the Mediterranean area.

Since infection, in nature, is completely dependent upon the presence of the vector the general distribution of the North American curly-top is limited to areas in which that insect normally occurs or into which it migrates. Annand and Davis report (5) good evidence of flights covering a distance of about 300 miles and Carter (6) suggests that they may easily be drawn into the upper air currents and thus carried for great distances. DeLong reported (7) *C. tenellus* from as far east as Florida but no plants infected by the curly-top virus have been reported in North America east of 91° W. Longitude and no proven cases of curly top east of 95° W.

Moisture (8) and low temperatures (5) have been reported as the most important factors limiting the natural habitat of the beet leafhopper. It is well known that these leafhoppers often migrate into the fog belt along the coast of California but they soon perish or move out. In areas where

Figure 2. Plantain, *Plantago erecta* Morris, 33 days after inoculation with curly-top virus strains. Left, strain 1; middle, strain 2; right, strain 3.

the vector is normally present we have four major factors which determine the spread of the disease. These are abundance of the vector, favorable hosts for the vector, favorable hosts for the virus and prevalence of the virus. If these factors are favorable the relative prevalence of different strains of the virus is most important in determining the amount of injury which may result.

Hosts for the Vector

C. tenellus has many hosts but a very high portion of them are not favorable; that is, the leafhopper will not breed on them and will not feed on them long if better host plants are available. Tomatoes, beans and melons are often seriously injured by curly-top but these plants are not favorable hosts for the vector. The leafhoppers survive only on living host plants.

Hosts for the Virus

As indicated earlier, the curly-top virus has a vast number of hosts and the virus may be recovered quite readily from most of these plants. Australia

saltbush (*Atriplex semibaccata* Brown) is a fairly good host of *C. tenellus* but rarely, if ever, a host for the curly-top virus. Severin (9) reported experimental infection of this saltbush but I have never been able to recover curly-top virus from it either as it occurs in the field or after inoculation in the greenhouse. Several species of mustard (*Cruciferae*) are good hosts of the leafhopper and some are good hosts for the virus, while others are apparently immune. Tree tobacco (*Nicotiana glauca* Graham) is a perennial host normally showing no symptoms but in which some of the more virulent strains of curly-top virus may live for several years. Russian thistle (*Salsola Kali* L. var. *tenufolia* Tausch.) is a good vrius host as well as an excellent host for the vector. Some California winter annuals such as *Plantago erecta* Morris, *Lepidium nitidum* Nutt. and *Erodium circutarium* L'Her. are good hosts for the vector and excellent hosts for the curly-top virus but greenhouse tests and field observations have shown (10) that, if infected while young, they may be rather unfavorable from the standpoint of actual quantity of virus produced and its dissemination. This is because the more virulent virus strains seriously dwarf and often kill such plants so that many leafhopper eggs fail to hatch and many virus sources are soon limited or destroyed (Figure 2). Young, susceptible sugar beet plants infected by the highly virulent strain of virus often react quite similarly but such plants receive water and cultural care which prolong their life and make them more serious as virus reservoirs.

Dead plants are not dangerous as curly-top virus sources because leafhoppers will no longer feed upon them.

Prevalence of the Virus

Assuming the presence of the virus in an area, its prevalence depends upon favorable virus hosts, favorable vector hosts and conditions which

Figure 3. Curly-top resistance breeding field near Twin Falls, Idaho. Planted May 3, photographed September 28, 1950. The eight rows in the center are R & G Old Type, a European variety which has been widely used, and yielding 2.58 tons per acre in these plots. At left is SL 824, yielding 17.42 tons, and at right is SL 92, yielding 20.50 tons.

favor the movement and activity of the vector. Warm, dry weather, a rather open stand of host plants and disturbances such as those caused by cultivation favor spread of the virus locally. The harvesting, plowing up or destruction otherwise of a good host plant crop such as sugar beet may result in serious spread of the virus to crops in adjacent fields even though these crops are not good vector hosts. Various factors, including the extreme drying or death of winter and spring vector hosts, encourage dispersal over wider areas and migration for very long distances. No practical methods have been demonstrated for leafhopper control in the winter and spring breeding areas or in sugar beet fields except where they are being grown for seed by the overwintering-in-the-field method (11) so that we have little control over disease spread by means of dusting or spraying.

Both field (10) and greenhouse (12) studies have indicated that virus concentration is appreciably less in resistant sugar beets than in susceptible plants. Field collections of leafhoppers show that the virus load in vectors from resistant sugar beets is significantly lower than in those from susceptible sugar beet varieties growing in adjacent or nearby comparable fields. This is an important factor in the spread of the disease either in the fields concerned or to other crops in adjacent fields. The fact that there are significant differences is also strong evidence that the vectors are likely to move relatively short distances once they have settled on a favorable host and under favorable conditions.

Figure 4. Left, beet var. SL 842 30 days after inoculation with virus strain 1. Right, beet var. SL 68 30 days after inoculation with virus strain 1.

Age of plants at the time of invasion by virus-carrying vectors has also been found (13) to have a pronounced effect on the percent of infection and the amount of injury. The older plants are much more resistant to infection and to injury. They are quite likely to survive, recover to an appreciable extent and serve as both excellent reservoirs of the virus and hosts for the vector. Old, infected beets which are left in the field over winter are good sources of virus and encourage the rapid spread of curly-top.

Strains of the Curly-Top Virus

Various strains of the curly-top virus (14) (15) further complicate the already complex picture (Figures 1, 2, 4 and 5). A large number of plant species are susceptible to all known strains of the virus. Most varieties of sugar beets are susceptible to all strains but some of the most highly resistant ones are extremely resistant to one strain which is highly virulent on European sugar beet varieties and on many other hosts. The less virulent strains do not infect tomatoes, melons, Turkish tobacco or resistant bean varieties. In the spring it is quite usual to find that the less virulent virus strains are far more prevalent than the highly virulent strains. As mentioned earlier, the highly virulent strains cause extreme dwarfing and frequently death among the more favorable winter and spring host plants in California and it is felt that these strains are thus self-limiting to a great extent. The same species of host plants infected by the less virulent strains continue for a comparatively long time as good hosts for the vector and as reservoirs of the virus (Figure 2).

It has been found that infection by the less virulent strains of curly-top virus does not immunize the sugar beet against the more virulent strains (16) (18) so that the prevalence of the less virulent strains among the first plants infected does not in any way avert the rapid spread of the more virulent strains to them.

Great progress has been made in the development of sugar beet varieties which are resistant to infection and highly resistant to injury by this

Figure 5. Left, beet var. SL 842 six weeks after inoculation with virus strain 11. Right, beet var. SL 68 six weeks after inoculation with virus 11.

virus complex (Figure 3) (17) but other virus strains more virulent than any thus far encountered may be discovered or may arise as a result of mutations, so it is essential to be on the alert for such developments.

The possible danger from such newly discovered virus strains is strikingly evident when you compare Figures 4 and 5. Until late 1947 virus strain

1 (Figure 4) was the most virulent that we had recorded on beet variety SL 68, but the virus selection 11 (Figure 5) was recovered from leafhoppers and beet roots from commercial fields at that time. It is practically as virulent toward SL 68 as toward SL 842.

Discussion and Summary

The great number and variety of host plants for both virus and vector makes it quite probable that some good hosts exist in almost any agricultural region. In order to carry virus and vector throughout the year there need to be, within not too great distances, hosts which constitute a succession upon which they can maintain themselves.

The climatic limitations of the vector are extremely fortunate help in restricting the spread of the curly-top disease in North America. It might be quite serious if *C. tenellus* should develop mutations capable of thriving in the colder and more humid areas.

Infected, living plants might easily carry the virus to new locations but the virus, without the vector, would be eliminated at the death of the host plants in which it had been shipped.

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Anatomical Studies of Injury to Sugar Beets Induced by Three Strains of the Curly-Top Virus

CHARLES F. LACKEY[1]

The object of these studies is to determine the tissues affected, the amount of tissue involved and the general histological or internal effects induced in susceptible sugar beets by curly-top virus strains 1, 6 and 22, obtained from N. J. Giddings. All three strains cause severe injury to susceptible sugar beets.

In Figure 1A are shown healthy checks of beets the same age as the infected ones. In 1B is shown a vascular bundle in a healthy beet petiole. Figure 1C is a cross section of a healthy root tip. Strain 1 produces rather severe symptoms on susceptible beets. It kills some beets in the very young stage but most of the beets infected when older live, although showing severe symptoms, and there are many cases of partial recovery observed. Figure 1D shows susceptible beets with the severe symptoms induced by strain 1.

In Figure 1E and 1F internal symptoms of curly-top are shown. In the root tips there is degeneration and necrosis of cells surrounding the sieve tubes as in Figure 1F. One or all may be involved. There is no uniformity in the degree of infection produced in these root tips. Figure 1E shows a cross section of a beet petiole with distinct areas of degeneration and necrosis in the phloem of the vascular bundles. Many times the phloem cells are regenerated so that the beet continues to grow in spite of the infection but will not make a very large root.

Virus strain 6 produces much less veinlet clearing or vein distortion than do the other virus strains but does dwarf the entire plant and is more lethal than virus 1, as shown in Figure 2A. It produces only small, inconspicuous necrotic areas in the phloem of beet petioles (Figure 2B); but it does cause severe necrosis in many cells in the sieve tube areas in root tips, as shown in Figure 2C. This strain is quite destructive to susceptible beets. While virus strain 1 usually causes necrosis and degeneration to only the cells surrounding the sieve tubes in root tips, virus 6 causes a great many other cells outside this area to become severely necrotic. This causes a rapid death of the root tips and dwarfs the top before killing it without affecting its tissues directly.

Strain 22, the most recent of the three to be selected, was obtained from a virus collection near Jerome, Idaho. It produces the most unusual symptoms of all strains tested and is the most injurious to both susceptible and resistant sugar beets. This strain produces very severe symptoms on the leaves of beets as shown in Figure 2D. It causes the greatest injury to the vascular

Figure 1. (See page 533.) Healthy checks and symptoms produced by virus strain 1. A. Healthy checks, same age as D; B, vascular bundle healthy beet petioles; C, cross-section healthy root tip; D, infected sugar beets; E, vascular bundle in petiole of infected beet showing necrosis and degeneration of phloem tissue; F, necrosis and degeneration of cells surrounding sieve tube in infected root tips.

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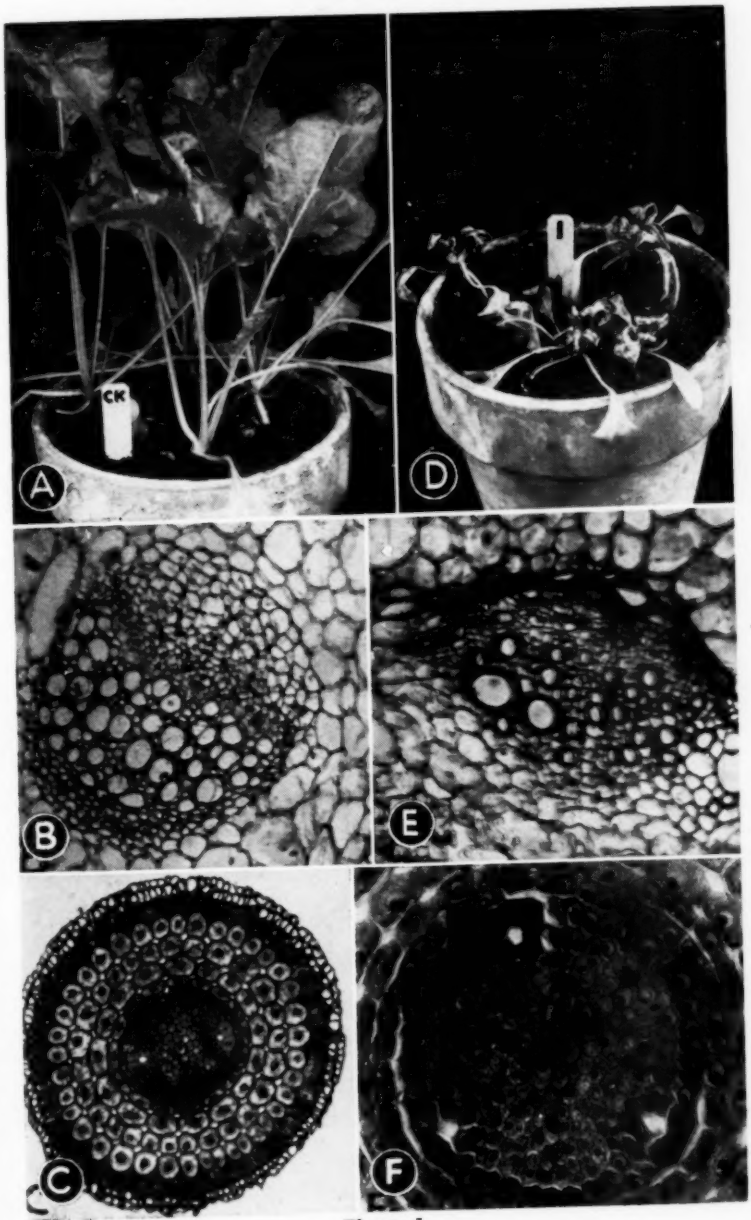

Figure 1.

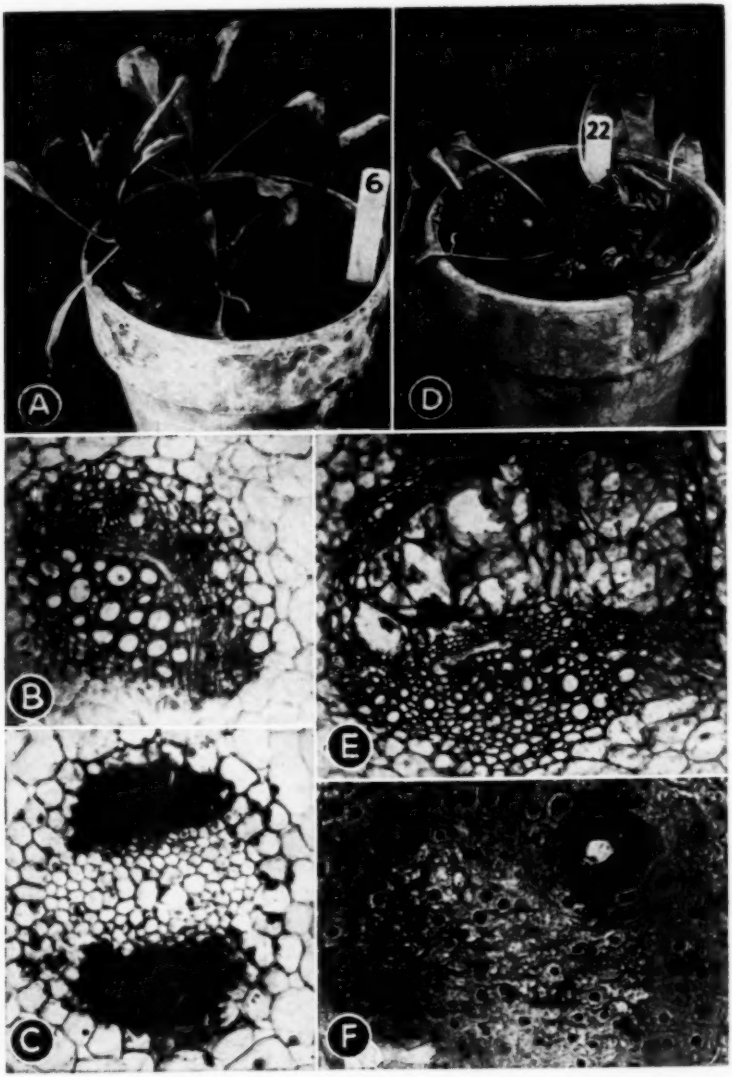

Figure 2.

bundles of the petioles of sugar beets. This injury consists of extreme hypertrophy of phloem cells with extensive necrosis and complete disorganization of the vascular bundles as shown in Figure 2E. This is a cross-section through a vascular bundle in a susceptible beet petiole.

Very mild strains of virus often cause hypertrophy in the phloem area of root tips and petioles without any degree of necrosis. Virulent strains like strain 1 will cause considerable necrosis but very little hypertrophy. Strain 22 produces both kinds of symptoms in the petioles of sugar beets and these prove to be the most destructive. However, extensive examinations of sectioned root tips from soil and nutrient solutions show few symptoms of curly-top in the tips of infected beets and these consist of only a few cells adjacent to the sieve tubes showing mild forms of degeneration (Figure 2F), in contrast to virus 6. Strain 22 does produce some bending and curling of root tips similar to that of virus strains 1 and 6. These latter strains produce root distortion by phloem necrosis. Strain 22 distorts by hypertrophy of cells surrounding sieve tubes and involving some tissue outside the pericycle.

Since virus strains 1 and 6 have been collected from two widely separated areas in California and strain 22 from Idaho, it indicates a widespread distribution of them.

Summary

Histological studies were made to determine tissues affected and degree of injury produced by three very virulent strains of curly-top virus.

Virus strain 1 causes rather severe injury to beet tops with vein roughening and distortion of leaves. In petioles it causes necrosis and degeneration of phloem tissue.

Virus strain 6 causes very little vein roughening or leaf distortion but does severely dwarf the entire beet plant. In petioles only a few small necrotic areas are produced, in the phloem tissue. The root tips are severely injured by extensive necrosis and degeneration of many cells in addition to those adjacent to sieve tubes.

Virus strain 22 produces very severe vein roughening and leaf distortion. In the vascular bundles of the petioles there is extremely severe hypertrophy and necrosis of the phloem and complete disorganization of the bundle. In contrast to virus 6 there are occasionally only a few cells surrounding sieve tubes in root tips which show mild degeneration.

Figure 2. (See page 534). Symptoms produced by virus strains 6 and 22 on susceptible sugar beets. A. Beets infected with virus 6 showing very little leaf distortion or vein roughening but severe dwarfing; B. vascular bundle in infected beet petiole showing only small necrotic areas; C, cross-section infected root tip showing severe necrosis and degeneration, involving many more cells than those adjacent to sieve tubes; D, beets infected with virus 22 showing severe top symptoms; E, cross-section vascular bundle in infected petiole, severe hypertrophy and necrosis of phloem tissue; F, cross-section of root tips showing only mild degeneration of a few cells surrounding sieve tube.

Virus Yellows in Western Europe

H. Rietberg[1]

At present, virus yellows is without doubt the most important virus disease of the sugar beet, fodderbeet and mangold (stockbeet) in various countries of western Europe. A considerable amount of information has been assembled by the specialists working on this problem and some of the main points are discussed here.

History and Distribution of the Disease

According to Professor Hudig there was a serious outbreak of the disease in the Zeeland area of the Netherlands in 1912 and in literature outbreaks of a disease which may have been virus yellows have been mentioned even earlier. In 1934, Quanjer recognized the disease as a virus disease and in 1935 successful transmission by means of aphids was made both at Wageningen and Bergen op Zoom. In 1937 and 1938, the first attempts were made in field experiments to estimate the losses caused by this disease. A difficulty in the earlier years of work on this subject has been that beet leaves can turn yellow for many reasons. In some cases even now it is difficult for a specialist to recognize the disease without laboratory tests.

The disease is definitely known in the European countries of Sweden, Denmark, Western Germany, Netherlands, Belgium, England, Ireland, France, Switzerland and Austria. It seems to be penetrating into eastern Germany and according to some reports occurs also in Czechoslovakia, Jugoslavia and northern Italy. The most serious attacks of the disease up to now have occurred in England, Netherlands, Belgium, parts of western Germany and parts of Denmark. The incidence of the disease in the different countries varies considerably from year to year.

Symptoms of the Disease

The symptoms may vary considerably due to climatic conditions, variety, "strain" of virus, time of infection, etc. The main characteristics are:

1. Yellow to orange color of leaves or parts of leaves and in some varieties also small reddish spots or formation of anthocyanin;
2. Leaves thicker and brittle, breaking along a straight line when folded up;
3. Formation of "gum" in the phloem;
4. Accumulation of photosynthates in the leaf;
5. Stunting of growth.

The first yellow symptom often shows at the top of the leaf, but also sometimes at other portions. First of all a slight mottling and discoloration is seen and this develops gradually into bright yellow. At first, often only a sector of the leaf between two major veins becomes yellow. Another symptom, which by some specialists is ascribed to another "strain" of the virus, is the clearing of the veinlets in a part of the leaf. Also sometimes

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small necrotic spots develop which merge together to form larger necrotic spots in a later stage. Red spots are formed on some sugar beet varieties while in mangolds the anthocyanin sometimes completely covers the yellow color.

The thickening of the leaves and the yellowing are almost always correlated. Both in the greenhouse and in the field, however, plants can be found with thick brittle green leaves in which the yellowing symptoms come later, especially when the weather is overcast for a long time. Mostly the yellowing does not begin on the oldest leaves but on somewhat younger leaves, while the heart leaves remain green.

The gum formation in the phloem was discovered by Quanjer in 1934. It is, however, found in some green healthy plants also, but usually less prominent and therefore, cannot be used as a single, characteristic symptom for recognizing the disease.

Accumulation of starch and reducing sugars is always found in the yellow leaves unless these are old and already partly necrotic. The growth of the foliage is stunted, especially with early infections. Excessive development of weeds is therefore very often seen in fields in which virus yellows is prevalent.

In cases of doubt the use of the serological method of diagnosis is very helpful.

Vectors and Sources of Virus

The most important vectors are *Myzus persicae* and *Aphis fabae*, although it has been proved that at least in greenhouse experiments some other aphids are also able to transmit the virus. Various other insects living in beet fields have been tested but, so far, apart from aphids, no other vectors have been found. In many cases *Myzus persicae* is the more dangerous vector as it moved around more in the fields, while *Aphis fabae* forms colonies on a plant or a group of plants. In some areas, however, *Aphis fabae* under favorable conditions develop in such numbers that without any help from *Myzus persicae* a hundred percent infection is reached. The spread of the disease by alate aphids is greater than that caused by apterous ones and it is still an unsolved problem as to which is the role of the alatae of other species which may feed but not breed on beets.

The plants susceptible for Virus Yellows all belong to the Chenopodiaceae or closely related families. The following sources of virus should be mentioned:

1. Wild plants of the families mentioned above.
2. Beet seed crops.
3. Mangold clamps.

Apart from *Beta maritima*, which may play a role in some districts along the coasts, most of the weeds belonging to the Chenopodiaceae are annuals. In some countries and under mild weather conditions, however, some of these may overwinter and carry the virus. In parts of Belgium and some villages of the Netherlands the same may be the case with overwintering spinach. When beet stecklings are infected in summer or autumn the seed

crop will carry the virus early in spring and be a dangerous source of virus, as has been recognized in many countries.

The most dangerous source, however, in some European countries is formed by the mangold clamps present on many farms. These mangolds are used for feeding cattle even until May or June. In the clamps (pits) not only the virus overwinters, but also aphids live over winter on the sprouts. Under favorable conditions these aphids may breed in enormous numbers and a clamp may contain millions of aphids. When the clamp is opened in the spring, the alate aphids migrate to the fields and cause a primary infection as has been proved by the late Dr. Hellinga (Bergen op Zoom) as far back as 1942. Later on, aphids breeding in the field or migrating from other sources, e.g., peach trees) will spread the virus from these spots of primary infection. When great numbers of alatae are present in summer a few spots of primary infection are sufficient for a heavy outbreak of the disease.

In some cases no spots of primary infection are found. We have noticed this sometimes when the source of virus was a beet seed or spinach seed field with a high degree of infection from where great numbers of winged aphids moved early in summer. No transmission of this virus by seed has been found.

Losses Caused by the Disease

In England, losses were calculated at 4 to 5 percent of the yield of healthy plants for each week that symptoms are showing until mid-October. This comes to 40 to 50 percent for mid-June infections as compared with 30 to 40 percent for the same in experiments in Sweden and the Netherlands. Maybe the strain of virus used in the English experiments has been more severe. The sucrose content may be reduced by 1 or 2 percent. Also, there is an increase in noxious nitrogen and the purity of the expressed juice is lower. In the seed crop, losses of yield of over 100 pounds per acre per 10 percent increase in virus yellows may occur, as has been proved by Hull in England. The quality of the seed is also lower.

Influence of Cultural Practices

It has been found that early planting and high population have an effect. Young plants are more attractive to aphids and they prefer an open stand. Aphids will not colonize so much in a well closed stand, probably because they find an unfavorable ecoclimate. On the other hand, some aphid parasites develop better in a closed stand.

As a general rule it can be said that good farming practices, early planting, high plant population and, to some extent, the use of fairly heavy dressings of nitrogen will help the farmer to reduce the percentage of infection. In typical virus yellows years the effect from nitrogen will be limited.

Means of Combating the Disease

Apart from the cultural practices mentioned above, there are a few other methods of combating the disease.

Stecklings should be grown in areas where the environment does not suit the vector or where beets and other hosts of the virus are more or less

absent. This pracice has been adopted in Sweden, Netherlands and, in part, in England. Virus infection of stecklings has been reduced by growing them under cover crops. Spraying with systemic insecticides has also given good results with the exception of those cases where there are great numbers of viruliferous alate aphids about.

For mangold clamps the best advice, up to now, has been to feed the mangolds before the beginning of April. Experiments in the Netherlands, where on one of the islands all clamps were removed, have shown a reduction of virus yellows in 1950 and 1951. Experiments on fumigation of aphid-infected clamps have not been very successful.

Apart from the necessity of breaking the overwintering cycle of the virus in various hosts, there is a possibility for combating the disease in the commercial beet crop by using systemic insecticides. Although experiments have shown fairly satisfactory results, the possibilities are not yet sufficiently explored to know whether this will develop into a paying proposition for the beet grower.

The primary infection by aphids is not prevented by the use of systemic insecticides and, therefore, in cases where there is a large number of winged viruliferous aphids present, a high percentage of infection will occur in fields sprayed with systemic insecticides.

A resistant variety would undoubtedly be the best solution. Some of the specialists do not believe in resistance to virus yellows, but the recent work carried out at Bergen op Zoom and in other countries has shown that there are lines showing a higher degree of tolerance against this disease than others.

The work is difficult since symptoms are often more or less masked, but personally I feel sure that when breeder and pathologist work closely together it can be done. Not only will attention have to be paid to commercial varieties and breeders' lines, but we must thoroughly explore the behavior of the wild relatives of our sugar beet.

Sugar Beet Virus Yellows Situation in the United States

G. H. Coons[1]

Since the first reports of the occurrence of sugar beet yellows in Europe, and especially after the investigations by Quanjer (7)[2], Roland (8), Watson (11), and others definitely established its virus nature, numerous attempts have been made to determine whether the disease occurs in the United States. The earlier European accounts were somewhat conflicting and the symptoms of the disease were not clearly described. The black and white photographs gave little idea of the effects on individual plants, or of the field aspect of the disease. It had been shown that plants exposed to virus-bearing aphids became the foci of virus infection when taken to the field. In many cases, the success of inoculations was determined by the capacity of inoculated plants set out in the field to become infection centers.

Much of this early evidence seemed at variance with American experience with virus infections, so that considerable skepticism concerning virus yellows existed among plant pathologists here. Any such confusion has now been entirely corrected by the critical research in the Netherlands, France, England, Belgium, Germany and elsewhere, so that now virus yellows is recognized as a distinct disease complex concerning which there is definite concordance of views among experts.

The beet sugar industry of Europe was extremely slow to believe that the yellowing of fields, which took place in early August or which in some years was deferred, was assignable to disease and not the result of early ripening, drought, excessive moisture, nutritional deficiencies or soil conditions. Many of these conditions do cause plants to take on a yellow appearance, but these may be definitely separated from the virus yellows syndrome.

It now seems clear that virus yellows is not a new disease in Europe. Authentic reports in the Netherlands of a yellowing of fields of the same character as those which occur nowadays date from 1912[3]. In Denmark, E. Gram (3) believed there were acceptable records from that country as far back as 1914. In Belgium, the reports indicate that in 1925, 1927, 1928 and, above all, in 1929, virus yellows was generally present and destructive. In England (11) the disease was identified in 1940, although it had been suggested in 1935 that the disease might be present. Apparently the outbreak of virus yellows in Germany is relatively recent—1937 (9).

Beginning in 1934 and continuing over many seasons, sugar beets showing symptoms which appeared to correspond to European descriptions of virus yellows were collected from commercial fields in Michigan, Ohio and Colorado, and taken to the greenhouse where aphids were colonized upon them. The aphids were transferred to healthy plants to determine whether a virus was present. Attempts at mechanical inoculation were also made.

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[2] Numbers in parentheses refer to literature cited.

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Consistent failures from all attempts had almost lead to a fixed opinion that virus yellows was not present in United States and that we should look to other factors to explain the types of yellowing which occurred with us.

On September 26, 1940, the writer noted in the field at the Colorado Agricultural Experiment Station, Fort Collins, Colorado, where sugar beet agronomic experiments were being conducted, that the edges of the field and certain spots 30 to 50 feet in diameter were conspicuous because of sugar beet plants whose outer leaves were yellow, especially at the tips of the leaves. The condition was designated at the time as "brittle yellows." Similar observations were made in September, 1947. About the same time, A. C. Maxson and H. E. Brewbaker reported to the writer that they had observed for several seasons a yellowing of foliage which began to develop about mid-season in a few sugar beets growing near the Great Western Experiment Station at Longmont, Colorado, and that this yellowing before the end of the season would apparently involve almost all the sugar beets growing in the plot in the immediate proximity of the Station.

In the fall of 1949, many yellowed plants having symptoms which apparently conformed to those of virus yellows in Europe were collected in Michigan and Colorado. Because of the high incidence of sugar beet mosaic in the plants, they were grown in the sugarcane greenhouse at Plant Industry Station at Beltsville, Maryland, in order to avoid chance of mosaic spreading to other sugar beet cultures at the Station.

Dr. Rietberg[3] in February, 1950, brought anti-yellows serum (1) as prepared by the Laboratorium voor Bloembollenonderzoek at Lisse, Netherlands, to Beltsville, Maryland, together with apparatus and other check sera as necessary for testing for presence of virus yellows in suspected plants.[4] He trained the late Dr. J. E. Kotila and the writer in the technique but was not able, during his brief period at Beltsville, to demonstrate the presence of virus in suspected plants.

No positive results were obtained in later work during that spring. We now know that the spontaneous flocculation which made it impossible to read the preparations was due to warm conditions in the greenhouse in which the plants were grown and the very warm room conditions when the juices were being extracted.

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[4] In the technique commonly followed at the Lisse Laboratory, the anti-yellows serum is obtained from a rabbit which has been repeatedly injected, at about two-week intervals, with juice from sugar beets showing typical virus yellows symptoms. When the rabbit has reached a high state of immunization to the yellows virus, it is bled and the serum separated. Such serum will keep for an indefinite period if frozen. Prior to making a test of suspected plants, it is necessary to saturate the serum with juice from healthy sugar beet leaves to remove any antibodies which might react with the protein of the normal sugar beet plant. Usually 0.1 cc. of serum is added to 1.0 cc. of juice from healthy leaves. After incubation at 37° C. for two hours, the juice—plus anti-serum—is kept for 24 hours at slightly above the freezing point. The solution is then centrifuged at high speed to obtain a crystal-clear solution for the tests. To test a suspected plant, mature or nearly mature leaves are pressed to obtain a small quantity of juice. This is diluted 50:50 with 0.9 percent NaCl solution. Small drops of approximately equal size of the anti-yellows serum, diluted as indicated, and the diluted plant juice are placed side by side on a cover glass. The drops are then mixed with a small glass rod. The test drop on the cover glass is then inverted and placed over a glass ring as a hanging drop. Vaseline is used to seal the cover glass to the van Tieghem ring.

After periods of one hour and two hours, respectively, at 37° C., the drop is examined under the microscope, a low-power objective and a darkfield condenser being used. Positive reactions are manifested by clouds forming in the drop and by flocculation of the minute particles into discrete clumps. With a negative reaction, the field remains free from clouds and the small particles are scattered. As checks, the juice from the suspected plant is tested against a serum prepared by injecting the rabbit with juice from healthy plants, and against normal rabbit serum. These are saturated with healthy juice as described for the anti-yellows serum. For a test to be acceptable, there must be no clouding or flocculation with the check sera.

In November, 1950, a new shipment of anti-yellows serum was sent by Dr. Rietberg, and in February, 1951, he again visited the United States. In tests with the anti-yellows serum from the Netherlands, Plant X-100—collected at Cone, Michigan, in September, 1950—was selected by Dr. Rietberg for the first tests because it showed a mild netting of the veins of older leaves. This plant gave positive reactions against anti-yellows serum entirely comparable with the reactions obtained with juice from virus yellows plants of the Netherlands known to have been affected with virus yellows which Dr. Rietberg had brought to the United States (2). Since that time, Michigan Plant X-100 and a companion plant from the same field, X-105, have been tested repeatedly and always with positive reactions. Frozen juice of Plant X-100, taken to Holland in June, 1951, gave positive readings in the serological tests conducted by Dr. J. A. Hijner.

During late winter and spring of 1951, many serological tests were made by the writer on suspected plants which had been collected in Michigan, Ohio, Colorado and with clones of Utah plants that had been maintained in the Beltsville greenhouse. Out of seven plants collected in Michigan and Ohio, positive tests were obtained from two plants as already mentioned. These plants giving positive tests gave such reactions consistently and the plants which were negative likewise remained negative. Out of twenty-six plants picked up in Colorado because of yellowed foliage, nine were positive, two probable and fifteen negatives. Two monogerm plants received originally from Salt Lake City in 1950, which had been maintained by cloning, gave positive reactions.

In the spring of 1951 aphids were colonized on plants which had given positive reactions, but all tests failed because of death of the aphids from parathion residues on the greenhouse plants.

Kassanis (5) reported that mechanical inoculation of sugar beets with virus yellows was possible, about ten percent of the plants becoming systemically infected. When plants were kept four days in the dark, three times as many became systemically infected. Juice inoculations were tried in two experiments in which sap from the leaves of Michigan Plant X-100 was rubbed on the leaves of healthy sugar beet plants following a light dusting of the leaf surface with carborundum powder.

In the experiment performed March 17, 1951, fourteen plants of the variety SP 503036-01 in about the six-leaf stage were so inoculated and one plant, No. 11 of the series, showed a yellow spot about four millimeters in diameter on March 22. Yellow spots or blotches continued to appear on the new leaves which developed on this plant. The spots were sometimes circular, but usually more of a lemon-yellow blotch. One week later juice was pressed from the leaf, which had been kept in the icebox, and the juice tested as antigen against anti-yellows serum. It gave a positive test. Attempts to colonize aphids on Plant No. 11 failed because of death of the aphids.

On April 19, 1951, nine plants of the variety 46108-01, which were about seven months old, were similarly inoculated with sap of X-100. These plants and three companion plants had previously been placed for six days in the dark in a refrigerated cold-storage room where mother beets are kept. In the April 19 inoculations, two or three leaves per plant were

dusted with carborundum and then rubbed lightly with juice obtained by grinding a leaf of Plant X-100 in a mortar. Nine plants were so inoculated with juice from X-100; three other plants were rubbed with water as check. Untreated plants of the same planting stood nearby. On May 14, 1951, all plants including the checks and the untreated plants, except Plant No. 5, were normal. Plant No. 5 was noted as having a suspicious mottling not unlike beet mosaic but occurring everywhere throughout the leaves. Some excrescences had formed at the scratches. The juice of a leaf of this plant was squeezed out on June 8, frozen, and taken in the frozen condition to Netherlands by air where it was tested along with many other frozen juices by Dr. Hijner. The juice of Plant No. 5 of the April 19 inoculation gave a positive reading, tests being made in the blind by Dr. Hijner, Dr. Rietberg and the writer. Juice from a check plant (Plant No. 12) similarly treated gave negative results.

In August and September, 1951, Dr. Raymond Hull of the Rothamsted Experiment Station, who is stationed at Dunholme, England, and is a specialist on virus yellows (4), traveled in Colorado, Utah, Oregon, California and Michigan. In his inspection of sugar beet fields, he found plants with typical virus yellows aspect in all states visited. In Colorado and Utah, he found such plants only in close proximity to greenhouses or seed plots where mother beets could have carried over the virus. Yellowed plants of this type were not found in commercial fields. In Oregon he found red garden beets and volunteer sugar beets growing in the stubble of a recently harvested sugar beet seed crop which he suspected of being diseased with virus yellows.

Both red garden beets and sugar beets collected in Oregon and brought to Beltsville have given positive serological tests. Plants taken from Colorado fields in which Dr. Hull had noted plants with a typical virus yellows aspect have also been shipped to Beltsville. These have given positive serological reactions. Plants from the greenhouse of the U. S. Sugar Plant Field Laboratory at Salt Lake City, Utah, where Dr. Hull suspected virus yellows to be prevalent, have also given positive reactions whereas seedling plants collected from a field at a distance from the greenhouse have given negative reactions.

At Salinas, California, Dr. Hull investigated a condition of sugar beets which had been noted for several years and was spoken of as "Salinas yellows." By mid-August the fields had become almost totally yellow. One field (Salinas Vegetable Growers' Exchange field) was noted in which the yellowing occurred only as a few limited areas, resembling the early stages of the disease in European sugar beet fields. The symptomatology shown by the yellowed plants in California was entirely comparable to that of European plants known to be affected with virus yellows. This was so stated by Dr. Hull.

During October 22-25, C. W. Bennett, E. Carsner and the writer inspected sugar beets fields near Salinas, Clarksburg and Linden, California. The extreme yellow phase was being succeeded by a green growth of inner leaves, but the fields still had a yellow cast and the outer leaves were yellow and brittle, resembling virus yellows as seen by the writer in Europe. Curly-top and severe red spider injury which had obscured the disease symptoms

in other years were almost absent in 1951. The field of the Salinas Valley Vegetable Growers' Exchange was now totally infected.

Plants had been collected from the fields visited by Dr. Hull by Dr. J. S. McFarlane. Additional collections were made at Salinas, Spreckels, Clarksburg and Linden. These were shipped to Beltsville, Maryland. Juice also was expressed from fresh leaves, frozen and shipped to Beltsville. Representative material from the California collections has given positive reaction with the anti-yellows serum supplied by Dr. Rietberg.

Dr. Pierre Limasset of the Station Centrale Pathologie Vegetale, Versailles, France, in January, 1952, tested juice from suspected plants with an anti-yellows serum which he had produced at the Versailles station. With the technique in use at Versailles (6), leaves from plants sent from Spreckels and elsewhere were tested serologically with positive reactions. Dr. Limasset stated that with a reaction so specific as that of virus yellows protein against an anti-yellows serum that he had no doubt of the presence of virus yellows in California and in Utah, as a result of the tests he had conducted.

Aphid transmissions of virus yellows have been accomplished, using both Oregon and California plants as virus sources. Plants collected in Oregon by Dr. Hull, and plants from the Salinas, California, fields that he visited, had been growing under quarantine at Plant Industry Station, Beltsville, Maryland. Several transmission tests started in November and December, 1951, gave positive results. One of these is cited since an Oregon plant was used as a virus source.

A test was made using a sugar beet (No. 2) collected by Dr. Hull in Oregon as showing virus yellows symptoms. Aphids (*Myzus persicae*) had fed on this plant for a few weeks. On November 14, 1951, small pieces of two yellow outer leaves, each piece with about ten aphids, were placed on healthy sugar beet seedlings in the four-leaf stage. The aphids promptly moved to the test plants. The next day, aphids were noted as feeding. Three days later the aphids were killed by nicotine spray and the plants were placed in the quarantine greenhouse. On December 12, 1951, and January 29, 1952, four out of nine inoculated plants were found to show yellow, brittle leaves typical of virus yellows. Five check plants in this experiment not exposed to aphids remained healthy. Three of the plants diagnosed as positive were tested with anti-yellows serum and gave positive reactions. One check plant was tested serologically and was found to be negative.

The aphid transmission test started December 13, 1951, is reported in detail. Aphids [5] had been colonized for nearly a month on a plant from the Jensen field (Salinas 1) and on a plant from the Jacobs field (Salinas 2). A piece of leaf carrying approximately ten aphids was placed alongside a healthy plant in the two-leaf stage and the aphids allowed to crawl to the young plant. Observation was made the next day and, in all cases but one, feeding was recorded as positive, and this one was questioned.

Repeated examinations of these plants showed absence of veinlet clearing. The signs of disease were very obscure or absent until January 31 when

[5] Obtained from the stock cultures of Dr. Floyd F. Smith, Bureau of Entomology and Plant Quarantine.

Table 1.—Results from Inoculation Test in Which Plants from Jensen Field (Lot 1) and Jacobs Field (Lot 2) Were Sources of Inoculum. Ten Apterous Aphids *(Myzus Persicae)* Were Placed on Healthy Two-leaf Stage Sugar Beet Plants, December 13, 1951. (Read Jan. 31, 1952, and Feb. 1, 1952. No Veinlet Clearing)

One Plant—Salinas Lot 1						One Plant—Salinas Lot 2						Check					
		Readings 1/31/52 and 2/1/52						Readings 1/31/52 and 2/1/52						Readings 1/31/52 and 2/1/52			
Plt. No.	Aphids	Feeding 12/14	Color Oldest Leaf	Texture	Serum Test	Plt. No.	Aphids	Feeding 12/14	Color Oldest Leaf	Texture	Serum Test	Plt. No.	Aphids	Feeding 12/14	Color Oldest Leaf	Texture	Serum Test
1	10+	+	Yel.	Br.	+	11	10+	+	Yel.	Not Br.	—	20	0	—	pl. yel.	nor.	—
2	10+	+	Yel.	Wil.	—	12	8	+	pl. yel.	Br.	—	21	0	—	pl. yel.	nor.	—
3	10+	+	Yel.	Br.	+	13	10	+	yel. bl.	Br.	+	22	0	—	pl. yel.	nor.	—
4	10+	+	Yel.	Br. th.	+	14	10	+	pl. yel.	Sl. br.	+	23	0	—	pl. yel.	wil.	—
5	10+	+	Pale	Sl. Br.	—	15	10	+	pl. yel.	Sl. br.	±	24	0	—	gr.	nor.	—
6	10+	+	Yel-Gr.	Br. th.	±	16	10	+	pl. yel.	Br.	+	25	0	—	pale	nor.	—
7	10+	+	Gr.	Br.	+	17	10	+	pl. yel.	Sl. br.	+	26	0	—	gr.	nor.	—
8	10+	+	Gr.	Br. th.	+	18	10	+	pl. yel.	Sl. br.	—	27	0	—	pl. yel.	nor.	—
9	10+	+	[1]Gr-Yel.	Br.	+	19	5	±	pl. yel.	Sl. br.	—	28	0	—	gr.	nor.	—
10	10+	+	[1]Yel.	Not Br.	—							29	0	—	blan.	nor.	—
												30	0	—	gr.	nor.	—

[1] Lowest leaf dead; next one read.

Abbreviations key: Yel. = yellow; Gr. = green; Br. = brittle; Wil. = wilted; Th. = thick; Pl. = pale; Sl. = slight; Blan. = blanched; Bl. = blotched; Nor. = normal

Table 2.—Results from Inoculation Test in Which a Plant from Salinas Valley Vegetable Growers' Exchange Field was the Source of Inoculum. Aphids Were Colonized One Month on this Plant, Then Transferred on Jan. 8 to Test Plants, About 25 Aphids Per Plant. Test Plants Were in Two- to Four-leaf Stage. Feeding Period was Two Days. (When Read on Jan. 29 and Mar. 21, no Veinlet Clearing was Noted.)

Check					On Plt. From Salinas Valley Veg. Gr. Exch. Field as Inoculum Source						
Test Plt. No.	Aphids	Condition of Lower Leaves 1/29/52	Condition of Lower Leaves 3/21/52	Results of Serological Tests[1]	Test Plt. No.	No. of Aphids Appl'd 1/8/52	Aphids Feeding 1/9/52	Condition of Lower Leaves 1/29/52	Condition of Lower Leaves 3/21/52	Decision as to Virus Yellows	Results of Serological Tests[1]
1	0	normal	normal	3/21 lost	13	25+	many	normal	normal	±	3/21 —; +
2	0	normal	normal	3/21 lost	14	25+	many	normal	brittle	+	3/21 +
3	0	normal	normal	3/21 lost	15	25+	many	normal	normal	—	3/21 ±
4	0	normal	normal	3/21 —	16	25+	many	normal	brittle	+	3/21 +
5	0	normal	normal	4/1 —	17	25+	many	normal	brit; th.	+	3/21 +
6	0	normal	normal	4/1 —	18	25+	many	normal	normal	—	1/29 —; 4/1 —
7	0	normal	normal	4/1 lost	19	25+	many	normal	brittle	+	4/1 +++
				4/2 lost	20	25+	many	normal	brittle	+	4/1 +
8	0	normal	normal	4/2 —	21	25+	many	normal	brittle	+	4/1 +
9	0	normal	normal	4/2 —	22	25+	many	normal	normal	—	4/2 —
10	0	normal	normal	4/1 —	23	25+	many	normal	brittle	+	4/2 ++++
11	0	normal	normal	4/3 —	24	25+	many	normal	normal	—	4/2 —
12	0	normal	normal	4/3 —	25	25+	many	normal	normal	—	4/2 —; —
					26	25+	many	normal	yel., brit.	+	4/3 +++
					27	25+	many	normal	normal	—	4/3 + (weak)
					28	25+	5 or 6	normal	brittle	+	4/3 +++
					29	25+	many	yel., brit.	brittle	+	1/29 +; 4/3 +++
					30	25+	many	yel., brit.	brittle	+	1/29 +; 4/3 +++
					31	25+	many	normal	brittle	+	4/3 ++
					32	25+	many	normal	normal	—	4/3 —
					33	25+	many	normal	brittle	+	4/3 lost

[1] Serological readings of — mean no flocculation with anti-yellows serum from Bergen-op-Zoom; ± means slight cloud, not clear positive; readings of +, ++, +++, and ++++ represent definite flocculation, heaviest virus concentrations giving the +++ and ++++ reactions.

samples were taken of the oldest leaves for serological tests. Then it was found that in very high percent of plants the first and second leaves, i.e. the oldest, of inoculated plants were greenish-yellow, thickened and brittle whereas leaves on the check plants usually were green or, if yellow, were a clear, bright yellow. Leaf texture of check plants was normal, tending to be more flaccid than brittle. As the juice was being squeezed for the serological tests, the brittleness of the leaves of many of the inoculated plants was very evident in contrast to the soft, yielding condition of the leaves of the check plants. Results of the tests are given in Table 1.

Failure to obtain pronounced symptoms of virus yellows in greenhouse culture in winter is characteristic of the disease (10). Attention is also called to the fact that the virus strain from the Salinas plants did not cause veinlet clearing. The strains of virus yellows recently investigated in Netherlands and England, in contrast to those studied earlier, show veinlet clearing of young leaves, a sign which assists in determination of positive reacting plants.

January 8, 1952, aphids (*Myzus persicae*) which had been colonized for a month on a plant from the Salinas Valley Vegetable Growers' Exchange field were placed on healthy sugar beet plants in the two- to four-leaf stage, about twenty-five aphids being used per plant. The aphids were confined by a glass cylinder placed over each plant. The next day, it was found that in all cases the aphids were feeding. Next day the aphids were killed with nicotine and the plants put in the quarantine greenhouse. After three weeks three plants which showed signs of brittleness of the first true leaf were tested serologically. Two of these plants gave positive reactions. One large plant in the check series which showed a bright yellow lower leaf was tested—it was negative.

The details of this test and the subsequent readings in which a high percentage of the inoculated plants became affected with virus yellows are reported in Table 2 along with results of the serological tests. These results are of particular importance because Dr. Hull had made most positive statements concerning this field, as showing typical virus yellows aspect.

The concordance of disease symptoms of European and American plants, as stated by experts who are familiar with virus yellows in Europe, and the experimental work to date with anti-yellows sera and the inoculation tests, including the last reported tests of aphid transmission, lead the writer to a definite conclusion—that virus yellows exists in United States and that the condition known as "Salinas yellows," together with the similar yellowing effects noted near Clarksburg and near Linden, are indeed manifestations of virus yellows. The presence of virus yellows in Oregon also has been demonstrated. On the basis of symptomatology and serum tests, it can be stated that virus yellows also occurs in Utah, Colorado and Michigan. The Michigan type of virus yellows is being investigated further.

Summary

Virus yellows of sugar beet, known as a widespread and serious disease of sugar and forage beets in Europe, has now been positively determined as occurring in Michigan, Colorado, Utah, Oregon and California. European specialists on virus yellows have confirmed the similarity of symptoms and have supervised serological tests of suspected plants. Utilizing anti-

yellows sera obtained from Lisse, Netherlands, and Versailles, France, positive tests have been obtained from plants collected in the states mentioned. Transmission tests with juice (Michigan plants) and with aphids, *Myzus persicae*, (California and Oregon plants) have given positive results. The disease known in California as "Salinas yellows," on the basis of aphid transmissions and serological tests, has been shown to be virus yellows. The virus causes yellowing and thickening of outer leaves and brittleness; veinlet clearing has not been noted.

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The Effect of Certain Soil-Row Treatments on Damping-off of Sugar Beet Seedlings Caused by Specific Fungi

F. J. Hills and L. D. Leach[1]

It is usually possible to obtain a healthy stand of sugar beet seedlings in California with seed treatment alone. There are times, however, when damping-off is too severe to be controlled by this method. This usually occurs in late spring plantings subjected to high soil moisture from rains or irrigation. The organisms most frequently involved in such attacks are *Pythium ultimum* Trow, *Rhizoctonia solani* Kuhn, or *P. aphanidermatum* (Eds.) Fitsp.

The beet water mold organism, *Aphanomyces cochlioides* Drechs., is an important causal agent in soils of the delta region of the Sacramento and San Joaquin rivers which have a high water-holding capacity and are acid to neutral in reaction. Fortunately, this fungus is more or less confined to that area. It has not been possible to achieve adequate control of this organism through seed treatment. It would be desirable to have a method of controlling severe incidences of damping-off which could be applied to initial plantings of fields with a history of severe attacks and in replanting other fields when stands are destroyed.

Recent experiments by Hildebrand, Koch and McKeen (2)[2] (3) (4) have shown that a soil-row treatment with certain fungicides is a promising means of controlling damping-off. Their greenhouse work reported to date has been with naturally infested soils in which *A. cochlioides* appears to be the primary causal organism. Compounds such as Arasan (50% tetramethyl thiuramdisulphide) have been applied at rates of three to four pounds per acre mixed with commercial fertilizers of low nitrogen analysis. From 300 to 400 pounds per acre of such a mixture was applied in the field (4) through planter fertilizer attachments so as to place the material as close as possible in the zone through which the seedlings emerge. These workers point out (2) (4) that the degree of control is closely associated with the extent to which the fungicide can be incorporated with the soil around and above the seed and that it is difficult to obtain such placement with the usual planter attachments. A limitation to the use of this method of application in California is the wide-spread use of high nitrogen fertilizers which cannot be placed close to seed without impairing germination.

Based on the considerations above, it seemed desirable, before attempting field trials with soil-row treatments, to investigate the effectiveness of promising fungicides in protecting seedlings against attacks by each of the organisms involved and to explore methods of application more suitable to local conditions.

This paper presents the results of a series of greenhouse trials with the above objectives in mind. From the standpoint of eventual field use two methods of fungicidal application were considered for greenhouse work: (a) Dry applications, mixing the fungicides with non-toxic carriers such as gypsum or sugar factory lime, to be applied through planter attachments.

[1] Respectively, Extension Agronomist and Plant Pathologist, University of California, Davis. The senior author was Agronomist, Spreckels Sugar Company, when most of this work was carried out.

[2] Numbers in parentheses refer to literature cited.

(b) Spraying suspensions or solutions of a fungicide into the rows by means of spray nozzles attached immediately behind the planter shoes. The latter method has been stressed as it promises to give good placement of the fungicide.

Methods

To test the effect of treatments on specific organisms, soil was steam sterilized, then infested with the fungus under consideration. Six rows with forty seed units each were planted per flat. Processed seed (decorticated and sized 7 to 10/64th of an inch) of a standard commercial variety, usually U. S. 15, was used. For comparisons with soil-row treatments a sample of the same seed was treated with Phygon paste or Phygon XL, 0.25 percent by weight, the commercial treatment most commonly used in California. Treatments were applied to individual rows and were replicated from three to twelve times (usually six), depending upon the experiment. Generally a randomized block design was used with each flat constituting a block. Seedlings were counted daily. Diseased seedlings were cultured periodically to check on the pathogen involved. Each experiment was conducted over a period of four or five weeks after which the seedlings were dug and rated as to infection. "Healthy" indicated no sign of infection or that the seedling had materially recovered. Analyses of variance were used to evaluate results whenever data were suitable for such treatment.

Dry fungicide applications were made by mixing the fungicide with gypsum or soapstone and sprinkling the mixture into the row while covering the seed with soil so that the material was fairly well distributed throughout the replaced soil. Fungicidal solutions or suspensions were sprayed into the row by means of a hand atomizer. As with dry applications, sprays were applied so that the soil around and above the seed was well mixed with the fungicide.

Results and Discussion

The results of the various experiments are summarized in Tables 1 through 5.

Soil infested with *Rhizoctonia solani*. In trial number 1, Table 1, it can be seen that both Arasan and Dithane were effective in improving control over the standard seed treatment with Arasan giving better conrol

Table 1.—Effects of Soil-row Treatments on Damping-off Caused by *Rhizoctonia Solani*.

Treatments[1]			Trial 1[2]		Trial 2[3]	
Material	Amt. per acre	How applied	Emergence	Healthy survivors	Emergence	Healthy survivors
			(seedlings per 100 seed units			
Control	...	....	77	13	46	16
Arasan	3 lbs.	dry	136	86	—	—
Dithane	2.3 qts.	soil row drench	131	50	—	—
Arasan SF	2 lbs.	spray	—	—	100	83
Vancide 51	2 lbs.	spray	—	—	88	60
Vancide 51	4 lbs.	spray	—	—	97	85
Significant difference. 19:1			29	15	21	14
Calculated F value			13.36[4]	64.31[4]	12.92[4]	46.22[4]

[1] All seed treated with Phygon paste (.25 gms. per 100 gms. seed)
[2] Means of six, eighty-seed unit, replicates.
[3] Means of six, forty-seed unit, replicates.
[4] Exceeds the 1% level of significance.

of post emergence damping-off. Trial number 2 indicates that Arasan SF at two pounds per acre and Vancide 51 at four pounds per acre, applied as soil-row sprays, gave equally good control of damping-off caused by this organism.

Soil infested with *Pythium ultimum*. In this experiment (Table 2) seed treatment was as effective as the soil treatments in controlling the pre-emergence phase of the disease but did not control post-emergence damping-off as well as any of the soil treatments. Arasan, Arasan SF and Ceresan M appeared to be equally effective and all were better than Lignasan, which contains a soluble form of ethyl mercury phosphate.

Table 2.—Effects of Soil-row Treatments on Damping-off Caused by *Pythium Ultimum*.[1]

Material	Treatments[2] Amt. per acre	How applied	Emergence	Healthy Survivors
			(seedlings per 100 seed units)	
No soil or seed treatment			84	16
Seed treated with Phygon			131	69
Arasan	3 lbs.	dry	133	98
Arasan SF	2 lbs.	spray	146	96
Ceresan M	1 lb.	dry	145	104
Lignasan	0.68 lbs.	spray	141	84
Significant difference 19:1			20	10
Calculated F value			12.23[3]	15.06[3]

[1] Means of six, forty-seed unit, replicates.
[2] The Arasan compounds were applied to supply equal amounts of TMTD. Ceresan M and Lignasan applications contain equal amounts of mercury.
[3] Exceeds the 1% level of significance.

Soil infested with *Pythium aphanidermatum*. In the first experiment (trial number 1) summarized in Table 3 the infestation was extremely severe. This is shown by the fact that, without soil treatment, only one seedling survived from the 960 treated and non-treated seed units planted. The Arasan SF soil-row spray treatment was, however, clearly superior to

Table 3.—Effects of Soil-row Treatments on Damping-off Caused by *Pythium aphanidermatum*.

Treatments[1] Material	Amt. per acre	Trial 1[2] Emergence	Trial 1[2] Healthy Survivors	Trial 2[3] Emergence	Trial 2[3] Healthy Survivors
			(seedlings per 100 seed units.)		
A—No soil or seed treatment		2	0	....	....
B—Seed treated with Phygon		47	0.2	63	4
C—Arasan SF	2 lbs.	94	20	....	....
D—Vancide 51	2 lbs.	....	....	133	63
E—Vancide 51	4 lbs.	....	....	118	63
F—Vancide 51	8 lbs.	....	....	132	90
Significant difference. 19:1		20[4]	....[5]	45	....[6]
Calculated F value		24.21[7]	....	6.01[8]	0.26

[1] All soil-row treatments were applied as sprays.
[2] Means of twelve, forty-seed unit, replicates.
[3] Means of three, forty-seed unit, replicates.
[4] Applies only to difference between treatments B and C. Too few seedlings in treatment A to include in analysis of variance.
[5] Analysis of variance obviously cannot be applied. The observed differences are probably highly significant.
[6] Analysis of variance applies only to difference between soil-row treatments. All are probably better than seed treatment.
[7 8] Exceeds the 5% and 1% levels of significance respectively.

Table 4.—Effects of Soil-row Treatments on Damping-off Caused by *Aphanomyces Cochlioides* (Trials 1 and 2).

Treatments[1]	Trial 1[2] Emergence	Survivors on 12th day	Final survivors[4]	Trial 2[3] Emergence	Survivors on 19th day	Final survivors[4]
	(seedlings per 100 seed units)					
No soil or seed treatment	162	64	0	155	95	5
Seed treated with Phygon	159	66	0	144	99	8
Arasan SF—2 lbs. per acre	151	120	1.3	115	92	21
Ceresan M—1-2 lbs. per acre[5]	162	95	0	136	102	5
Phygon XL—3 lbs. per acre	131	96	6.8	116	107	20
Significant difference 19:1	19	20	—[6]	20	NS	10
Calculated F values	3.57[7]	16.85[8]	—	5.63[8]	0.38	6.86[8]

[1] All soil-row treatments were applied as sprays.
[2] Means of six, forty seed unit, replicates.
[3] Means of five, forty seed unit replicates.
[4] The majority of the surviving seedlings were at least moderately infected.
[5] One pound per acre in trial 1 and two pounds per acre in trial 2.
[6] Too few seedlings survived to analyze by analysis of variance.
[7 8] Exceeds the 5% and 1% levels of significance respectively.

seed treatment in controlling damping-off caused by this pathogen. In trial number 2 Vancide 51 appears to give good control of this organism.

Soil infested with *Aphanomyces cochlioides*. While the results of the four experiments summarized in Tables 4 and 5 indicate that certain soil-row treatments have possibilities of improving the control of damping-off caused by this organism, it is apparent that this pathogen is much more difficult to control than the other three. It should be noted that the "survivors" in these experiments include "moderately" infected as well as healthy seedlings. Very few seedlings could be classified disease-free (healthy) in these trials. It is questionable as to how many of the moderately infected seedlings would survive under field conditions. It should also be noted in Table 4 that certain of these soil-row treatments may reduce total emergence. Note the effect of Phygon XL in trial 1 and Phygon XL and Arasan SF in trial 2. Unlike the other causal agents of this disease *Aphanomyces* causes little pre-emergence damping-off. Only in trial number 3 (Table 5) did and soil-row treatment improve emergence over non-treated or treated seed.

Table 5.—Effects of Soil-row Treatments on Damping-off Caused by *Aphanomyces Cochlioides* (Trials 3 and 4).

Treatments[1]	Trial 3[2] Emergence	survivors on 12th day	Final survivors[5]	Trial 4[3 4] Emergence	survivors on 16th day	Final survivors[5]
	(seedlings per 100 seed units)					
No soil or seed treatment	134	77	7	—	—	—
Seed treated with Phygon	130	85	6	113	63	3
Arasan SF—2 lbs. per acre	149	116	26	116	103	18
Vancide 51—2 lbs. per acre	—	—	—	113	102	10
Vancide 51—4 lbs. per acre	—	—	—	107	97	11
Significant differences 19:1	13	13	5	NS	17	NS
Calculated F values	5.57[6]	21.30[6]	42.65[6]	0.58	10.24[6]	2.05

[1] All soil-row treatments were applied as sprays.
[2] Means of twelve, forty seed unit, replicates.
[3] Means of six, forty seed unit replicates.
[4] All seed in this trial was treated with Phygon.
[5] The majority of the surviving seedlings were at least moderately infected.
[6] Exceeds the 1% level of significance.

The fungus attacks largely after the seedlings emerge and causes severe post-emergence damping-off. It is also apparent that infection by this organism is more chronic than is the case with the other pathogens. These characteristics of delayed and prolonged attack partially explain why seed treatment has failed to give control and why any type of fungicidal control may be relatively more difficult. Despite the greater difficulty of control, however, Tables 4 and 5 indicate that soil-row treatments substantially reduce post-emergence damping-off. The difference between seedling emergence and those surviving from 12 to 19 days after planting show that considerably less post-emergence damping-off occurred when soil-row treatments were used.

Field Trials

Equipment for applying soil-row sprays in field trials has been built by R. A. Kepner[3], for small scale plots, and by Austin Armer (1) for large scale trials. A limited number of field trials have been conducted but additional trials are necessary under a wider range of conditions before conclusions can be drawn.

Summary and Conclusions

Greenhouse trials were conducted to determine the effectiveness of certain soil-row spray treatments in controlling damping-off caused by each of the soil-borne pathogens of this disease in California. On the basis of these experiments it is felt that:

1. Compounds such as Arasan SF and Vancide 51 when used as soil-row spray treatments are superior to the standard seed treatment now in use for controlling damping-off caused by any of the pathogens.

2. Of the four soil-borne organisms, *Pythium ultimum, Rhizoctonia solani, P. aphanidermatum* and *Aphanomyces cochlioides,* the latter appears to be the most difficult to control.

3. Spraying a fungicide in the row as the seed is planted appears to be a promising method of application.

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Soil Treatment for Control of Black-Root of Sugar Beets

N. R. Gerhold, W. J. Henderson, J. A. Twomey[1]

In many of the sugar-beet-growing districts of eastern Colorado, pre and post-emergence damping-off of seedlings are responsible for either the abandonment or partial loss of stands in many fields each year. A disease commonly known as "black-root," is a major factor in obtaining adequate and uniform stands of seedlings. Isolations from diseased beets collected from these districts yielded pure cultures of *Pythium, Rhizoctonia* and *Fusarium* sp. In many instances only one of these organisms responsible for black-root of sugar beets could be isolated from individual seedlings, while in other instances two or all three of them were obtained from a single plant. Although the organisms responsible for black-root infection in a given area are well known, it is difficult to determine by general field observations and inspection which of them, either singly or in combination, produces the greatest incidence of disease.

During the past three years, field tests have been conducted to determine the effectiveness of different fungicides applied at various rates in the row with the seed at the time of planting.

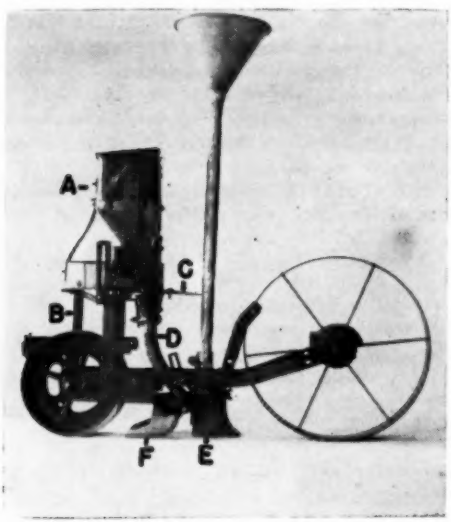

Figure 1. Planter Jr. equipped with a fertilizer attachment.

Procedure

The fungicides were applied to the soil with a Planter Jr. equipped with a fertilizer attachment (Figure 1). The fungicide to be applied was placed in hopper (A) at the rear of the planter. A mechanical device, operated by an off-set cam on the rear wheel (B), produced a shaking motion to the hopper. This insured an even flow of the fungicide material through an adjustable vent at the bottom of the hopper (C), into two flexible metal tubes (D) which directed the flow of material into the soil directly behind the seed applicator spout in the planter shoe (E).

The fungicide becomes mixed with the soil as the soil pushed over the top and sides of the planting shoe. The covering device (F) behind the

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planting shoe also helps to mix the fungicidal material with the soil. This method of applying the fungicide forms a protective band approximately 2½ to 3 inches wide and 1½ to 2 inches deep around the germinating seedling.

Soil-treatment plots, of a triple-lattice design, were employed in the field to evaluate the comparative effectiveness of the various soil-disinfectant materials. Nine replications of three 25-foot rows each were made for each of the soil-disinfectant materials, and also the non-treated check. Each quantity of the various fungicidal materials used per linear acre of row was thoroughly mixed with a given amount of finely screened sand for bulking purposes. Then the required amount of bulked material was applied per each 25 feet of row. Stand counts were made prior to thinning. The differences in stand counts of seedlings for the non-treated soil check and the treated soil were an indication of the comparative effectiveness in the control of the black-root disease by the various soil-treatment materials employed in the experiment.

Table 1.—Effectiveness of Various Soil-treatment Compounds in the Control of Blackroot of Sugar Beet Seedlings as Manifested by Comparative Stand Counts.

Treatment[1]	Rate[2] lbs. per acre	Average number plants per plot
Check	—	62.20
Fertilizer	75	61.62
Arasan	4	86.34
Ceresan "M"	½	55.46
Ceresan "M"	1	72.26
Dow 9-B	4	56.12
Orthocide 406	4	71.73
Yellow Cuprocide	4	66.44
Dithane Z-78	4	79.23
Phygon	2	67.44
Spergon	4	59.94
Crag 658	4	70.49
Dow D.H.A.	4	80.20
Parzate	4	56.11
Cadminate	4	73.80
Arasan	3	73.63
LSD 5% = 13.12		
LSD 1% = 17.31		

[1] Fertilizer, 12-24-0, at the rate of 75 lbs. per acre was added to each treatment with the exception of the check.
[2] Based on linear feet of row.

Experimental Results

The data compiled in Table 1 are the result of the 1951 field test and are quite typical of the results which were obtained in similar tests conducted in 1949 and 1950. The data, as given in Table 1, show that Arasan, Dow D.H.A. and Dithane Z-78, at the rates of four pounds per acre, significantly increased the stand of sugar beet seedlings over the non-treated soil check. These data further substantiate the results obtained in 1949 and 1950, except for Dow D.H.A., which was not included in the 1949 and 1950 tests. Ceresan "M," at the rate of one pound per acre, was found to be as effective as Arasan at the rate of four pounds per acre during the 1949 growing season. In the 1950 tests, Ceresan "M" at the rate of one pound

per acre decreased the average number of plants per treatment block compared to the non-treated check. The reduction in the number of seedlings compared to the non-treated check in 1950 was believed to be due to dry field conditions. Ceresan "M" being a mercury compound perhaps sublimed more readily under dry field conditions and caused injury to the germinating seedlings.

Of all the soil-disinfectant materials evaluated in the greenhouse and in the field, Arasan (50 percent) at the rate of four pounds per acre, gave the most consistent increase in the number of seedlings either in artificially infested soil or under natural soil-infested conditions in the field.

There were no significant differences in stand counts for any of the soil treatments after thinning and again prior to harvest.

Summary

1. In Colorado, "black-root" may be caused by pythium, rhizoctonia, fusarium, or an interaction between two or more of these organisms.

2. Soil-disinfectant materials were applied to the soil in the rows at the time of planting with a Planter Jr. equipped with a fertilizer attachment.

3. Arasan, Dow D.H.A. and Dithane Z-78, at the rate of four pounds per acre, significantly increased the stand of sugar beet seedlings over the non-treated soil check. These increases were significant at the 5 percent level. Arasan and Dow D.H.A. were significant at the 1 percent level. Ceresan "M," at the rate of one pound per acre, was as effective as Arasan at the rate of four pounds per acre in the 1949 tests in a season when there was an adequate soil moisture supply. However, because of dry soil conditions, Ceresan "M" at the rate of one pound per acre decreased the number of seedlings over the non-treated soil check in the 1950 tests.

4. Stand counts made after thinning and again prior to harvest failed to give significant differences.

5. Tests during the past three years show that Arasan applied in the row at the time of planting and at the rate of four pounds per acre, based on linear feet of row, gave the most consistent and significant results in controlling black-root of sugar beets and resultant increases of stand.

Cooperative Field Testing of Strains of Sugar Beets for Resistance to Several Root Rotting Organisms

A. R. Downie, M. L. Schuster, and R. K. Oldemeyer[1]

The task of breeding for resistance to root rot is not a simple one. There are many factors and interactions of factors which add to the difficulties involved. The problem of securing an artificial epidemic of a root rotting organism in a particular soil does not always meet with success. At the present, at least, it appears that resistance to root rotting organisms might be obtained by the adding of small increments and not in one single selection. It is, therefore, quite possible to lose what little resistance that might be present early in the process of selection. Also, the selection of "escapes" may quite often complicate the program, especially if the soil complex is at all unsuitable for the creation of an artificial epidemic.

Materials and Methods

The problem of obtaining artificial field epidemics for the four different root rotting organisms would be quite difficult at any one location. Fortunately the American Crystal Sugar Company had access to three Aphanomyces-infested field areas in Minnesota and Iowa and also to sclerotium-infested fields in California. The Great Western Sugar Company located a fusarium-infested field at Sterling, Colorado. The University of Nebraska, at the Scottsbluff Experiment Station, had a plot series which had grown sugar beets continuously for the past 40 years and the soil was badly infested with rhizoctonia. These locations served admirably for the testing of the various beet strains.

Table 1.—Results of Testing Beet Strains in Rhizoctonia-infested soil at Scottsbluff Field Station, Mitchell, Nebraska—1950.

Beet Strain	Germ. Stand Seedlings per ft. of row[1]	Final Stand in % of post-thinning stand[1]	Wt. of Beets 125 Ft. of row Unfertilized[2]	Fertilized[2]
Nebr. 525	13.5	56.1	51.6	133.3
G.W. B526	8.5	38.8	39.0	87.3
G.W. 304	7.0	51.2	45.6	129.1
G.W. 208	7.0	36.8	31.2	94.0
G.W. B116	5.0	52.9	37.8	130.2
A.C.S. 7-609-X	10.5	53.3	44.2	131.3

[1] Six replications, three unfertilized and three fertilized.
[2] Three replications.

Rhizoctonia Root Rot—1950

A test was made at the Scottsbluff Station in 1950 in which six beet strains were planted. The strains were G.W. 304, G.W. B526, G.W. 208, G.W. B116, A.C.S. 7-609-X and Nebraska 525. The latter was a selection for rhizoctonia resistance by Dr. M. L. Schuster out of the Great Western variety G.W. 526. The American Crystal strain 7-609-X was a selection for resistance to aphanomyces. The stand counts and the yields for this test are presented in Table 1.

The results of this test indicate that the Nebraska 525 selection was definitely superior to the parent strain G.W. B526. This superiority is the result of selecting over a period of two years. Also, it may be noted that

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the G.W. 304, which is a commercial variety, also ranked fairly close to the top as did G.W. B116 and A.C.S. 7-609-X.

Aphanomyces Root Rot Tests—1951

This cooperative effort was expanded in 1951 and tests were made using representative varieties for resistance to *Aphanomyces cochlioides*, Drechsler; *Rhizoctonia solani, Fusarium conglutinans* Wr. var. betae Stewart, and for *Sclerotium rolfsii* Sacc.

Figure 1.—Representative yields of four sugar beet strains grown in soil infested with Rhizoctonia at Scottsbluff in 1950. 1. A.C.S. 7-609-X. 2. Susceptible Strain. 3. G.W. B526. 4. Nebraska 525.

The tests for resistance to aphanomyces root rot were made at three places. The data for these tests are given in Table 2.

Table 2.—Yields of Beet Strains Selected for Resistance to Rhizoctonia, Sclerotium and Aphanomyces When Grown on Aphanomyces-infested Soil at Moorhead and at Waseca, Minnesota, and at Mason City, Iowa—1951.

Beet Strain	Originally Selected for resistance to:	Yield in Tons per A.			
		Moorhead	Waseca	Mason City	Ave.
A.C.S. 9-406-0	Aphanomyces root rot	11.41	12.16	8.66	10.74
A.C.S. 9-604-0	Aphanomyces root rot	9.75	8.61	7.76	8.71
Nebr. 525	Rhizoctonia root rot	6.30	4.46	5.44	5.40
A.C.S. 0-404	Rhizoctonia root rot	7.18	7.13	4.46	6.99
A.C.S. 0-403	Sclerotium root rot	6.37	5.52	4.95	5.61
Amer. No. 3 LSR	Commercial Variety	7.85	3.39	6.52	5.92
USDA 1-9-00	Very susceptible to Aphanomyces	3.62	1.52	3.86	3.00

The tests at Waseca and at Mason City were three replicate-randomized blocks while the test at Moorhead had six replications. In general, the beet strains behaved quite similarly at the three locations. The strains selected for aphanomyces resistance were highest in yield, while the strains selected for rhizoctonia and sclerotium pretty much fell in the same yield class as the commercial variety. The beet strain 1-9-00, which is the susceptible check, was the lowest in yield.

Rhizoctonia Root Rot Test—1951

A test similar to that which was made in 1950 was conducted on the

Table 3.—Yields and Stands of Beet Strains Grown on Rhizoctonia-infested Soil at Scottsbluff Field Station, Mitchell, Nebraska—1951.

Beet Strain	Originally Selected for resistance to:	Beet containing inches per 100 inches of row	Final stand in % of post thinning stand	Yield in tons per Acre
A.C.S. 9-604-0	Aphanomyces root rot	65	60.7	8.9
Nebr. 525	Rhizoctonia root rot	67	66.8	11.1
A.C.S. 0-404	Rhizoctonia root rot	53	54.7	6.7
A.C.S. 0-403	Sclerotium root rot	66	41.9	6.1
G.W. B526	Parent of Nebr. 525	57	38.0	5.7
G.W. 304	Commercial Variety	63	64.5	8.3

same rhizoctonia-infested, continuous beet plots, at the Scottsbluff Station in 1951. The results for this test are given in Table 3.

Comparison of the results obtained in 1950 and 1951 at Scottsbluff indicate that the beet strains behaved quite similarly in both years. The three beet strains which gave the highest yields in 1950 also gave the highest yields in the 1951 test. It is interesting to note in Table 3 that Nebraska 525 was almost twice as high in yield as its parent.

Sclerotium Root Rot Test—1951

The failure to obtain a good epidemic of this disease in 1950 not only made individual selections for resistance practically impossible, but also made it impossible to compare strains as to their resistance. The test in 1951 was much more conducive of results. The stand losses and the percent survival are presented in Table 4.

Table 4.—Performance of Sugar Beet Strains Grown in Field Soil Naturally Infested with *Sclerotium Rolfsii*, Clarksburg, California—1951.

Beet Strain	Originally Selected for Resistance to:	% Loss[1]			% Survivors
		Aug. 1	Sept. 1	Sept. 24	Sept. 24
9-604-0	Aphanomyces root rot	11.6	28.4	39.3	60.7
0-201	Sclerotium root rot	20.9	38.4	51.5	48.5
0-202	Sclerotium root rot	26.8	41.6	53.9	46.1
Am. No. 5	Commercial Variety	21.9	40.8	54.3	45.7
9-203	Sclerotium root rot	23.2	40.4	54.8	45.2
0-403	Sclerotium root rot	21.3	39.2	56.7	43.3
8-204	Sclerotium root rot	21.6	42.9	58.2	41.8
U.S. No. 15	Commercial Variety	30.8	50.0	66.4	33.6

[1] Percent loss based on comparison of thinned count of approximately 144 beets per 100 feet of row.

Beet strains 0-201 and 0-202 are selections of the mother lines obtained from beet strain 8-204 which is described by Lawlor and Doxtator (3)[2]. Beet strain 9-203 is a selection for Sclerotium resistance from U. S. No. 15.

The performance of the beet strain 9-604-0 is very surprising. This selection has never been exposed to sclerotium root rot since it is definitely a selection from a long line of varieties which have been found adapted to eastern areas where this disease has not been found. Also, it is of interest to note that the apparent resistance found in 8-204 has been transmitted to its selections. This same indication of the possibility of selecting resist-

[2] Numbers in parentheses refer to literature cited.

ant material was mentioned by Coons (1) and some selection work had been done on this problem. As far as the writers have been able to determine, the project was dropped.

Fusarium Yellows—1951

The test for resistance to fusarium yellows was made in a farmer's field at Sterling, Colorado. This field had been very badly infested in 1950 and was known to be extremely low in fertility. The test consisted of single rows of each beet strain running the entire length of the field. Each beet strain was replicated twice through the field. The results of this test were complicated by the occurrence of a fairly severe epidemic of rhizoctonia root rot in the west end of the field. The data as presented in Table 5 were obtained from the east end of the field where rhizoctonia root rot was not an important factor.

Table 5.—The Performance of a Group of Sugar Beet Strains Grown in Soil Naturally Infested with Fusarium at Sterling, Colorado—1951.

Beet Strain	Originally Selected for resistance to:	% Loss in Stand 7/19-9/21	% Healthy beets 9/21	Ft.	Roots	T per A.	% Suc.	S. per A.
G.W. 359	Commercial Variety	3.6	58.5	200	147	10.0	14.9	3,070
Nebr. 525	Rhizoctonia-resistant	9.1	21.6	200	157	9.9	11.9	2,349
C 404	Supposedly resistant to Fusarium yellows	11.4	18.0	100	68	6.8	12.4	1,673
G.W. 304	Commercial Variety	11.6	36.8	100	76	9.0	13.8	2,488
C 474	High Sugar selection from 304	13.4	44.6	200	136	8.6	14.5	2,477
A 123	USDA Aphanomyces res.	26.2	4.1		61	----	------	------

Visible symptoms of fusarium yellows did not appear until about August 15. During September differences in varietal reaction were evident. The data on percentage of healthy beets taken September 21 are based on the foliage symptoms.

The strains G.W. 359, G.W. 304 and C 474 were the most resistant to fusarium. At harvest time, on the basis of presence or absence of vascular necrosis, it was apparent that selections from G.W. 359 had the lesser amount of actual infection. Since sugar beets infected with this organism are likely to be lower in sugar percent than healthy beets (4), the relatively higher sucrose content of this variety further substantiates this finding. Also, under disease-free conditions Nebraska 525 and G.W. 359 usually have about equal sucrose content. This was certainly not true in this experiment.

Discussion

One of the remarkable features apparent in these tests is the tolerance of some beet strains to more than one root-rotting organism. The beet strain 9-604-0 shows considerable tolerance to aphanomyces, rhizoctonia and sclerotium. The beet strain was originally selected for resistance to aphanomyces. It is plausible that in selecting for aphanomyces resistance there was enough rhizoctonia present in the soil so that an automatic selection was made for resistance to this organism. However, it can be categorically stated that rhizoctonia certainly was not an important factor in losses of beets when

selections were made for aphanomyces resistance. There is no such probability that *Sclerotium rolfsii* might have been present in the soil at the time when selections were being made for aphanomyces resistance. This organism, which causes southern root rot, has never been reported from the areas where the aphanomyces selections were made.

From the foregoing, it might be deduced that selections with resistance to aphanomyces might also be resistant to rhizoctonia and sclerotium. Likewise, selections resistant to rhizoctonia are not resistant to aphanomyces. It is the belief of the writers that such conclusions may be a little too premature. Until more data is obtained or until the nature of resistance to the various root rots has been determined the above suppositions are not valid.

Another interesting feature is the apparent resistance of G.W. 304 to both rhizoctonia and fusarium. If this continues to hold true it certainly will lighten the load of breeding for resistance to these diseases, since this beet strain has done exceptionally well as a commercial variety and should be a desirable parent.

Summary

1. Various strains of sugar beets were tested on soils naturally infested with the fungi causing the following diseases: Aphanomyces root rot, rhizoctonia root rot, southern root rot and fusarium yellows.

2. Beet strain A.C.S. 9-604-0 was found to have resistance or tolerance to aphanomyces, rhizoctonia and sclerotium under the conditions of the experiments.

3. G.W. 304 appeared to have resistance or tolerance to rhizoctonia and fusarium. Also, the performance of Nebr. 525 definitely indicates that it is more tolerant to rhizoctonia than is its parent.

4. The selection Nebr. 525, which was made for resistance to rhizoctonia, did seem to have much resistance to aphanomyces.

5. The results of these tests indicate that there may be sources of resistance for these diseases and it may be possible to combine resistance to more than one root-rotting organism in a single variety of beets.

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Resistance and Soil Treatments for Control of Rhizoctonia of Sugar Beets[1]

M. M. Afanasiev and H. E. Morris[2]

Rhizoctonia root rot of sugar beets is a common disease of beets. Often only a trace of this disease is present, but sometimes severe epidemics occur which are very destructive. In 1949 at the Huntley Branch Station in Montana this disease caused more than 90 percent loss of stand in one field, and at harvest time there were only a few surviving beets free of infection. In previous years only a small amount of rhizoctonia occurred in this field. The outbreak of this disease gave an impetus to start investigations, conducted during 1950 and 1951, in which the effect of different nutrients, various nitrogenous compounds and fungicides was studied on the severity of infection of sugar beets with rhizoctonia. Resistance of beet varieties to this disease was also studied. These tests were conducted under greenhouse and field conditions.

Greenhouse Experiments

The soil from the infected plot at the Huntley Station and disinfected (N. I. Ceresan), segmented sugar beet seeds (U. S. 22 and 268) were used in these experiments. Beets were usually grown six weeks. Several times during this period and also at harvest time readings of healthy and diseased plants were made.

1. Effect of nutrients on the infection of beets with Rhizoctonia.

The soil was distributed into eight flats (20 inches by 12 inches by 3 inches) and was fertilized with the following substances:

Flat	Fertilizer	Disease developed percent	Flat	Fertilizer	Disease developed percent
1	NPM	69.5	5	N	65.2
2	NP	90.3	6	P	87.7
3	NM	68.1	7	M	70.8
4	PM	86.5	8	Check	74.1

Nitrogen was applied in the amount of 7.1 grams (mixture composed of one-half sodium nitrate and one-half ammonium sulphate); phosphorus, 7.1 grams of treble superphosphate, and manure (M), one-fifth of the volume of the soil. Three rows of seeds, 40 seeds per row, were planted in each flat of soil.

A considerable amount of disease occurred in all flats. The highest infection (90.3 percent) occurred in the soil treated with NP and the lowest in one treated with N (65.2 percent). On the whole, the addition of various nutrients had very little differential effect on the severity of the disease.

2. Effect of Arasan on the infection of beets with Rhizoctonia.

Sugar beets were planted in the same flats used in the first experiment. No additional fertilizers were added to the soil. Each flat was divided crosswise into two equal parts by insertion of a wooden partition in the box. Each half of the soil in all flats was treated with Arasan and the other half

[1] Contribution from Montana State College Agricultural Experiment Station. Paper No. 258, Journal Series.

[2] Plant Pathologist and Head, respectively, Department of Botany and Bacteriology, Montana State College.

left untreated. Arasan was used at the rate of 3 pounds per acre and the amount applied was prorated on the basis of linear feet of sugar beet row per acre. The chemical was mixed with fine sand and uniformly spread over the surface of 2-inch-wide strips, where the seeds were to be planted. The soil in these strips was worked to a depth of 1¼ inches. The seeds were planted ½ inch in depth in the center of these strips.

In several flats plants grown in treated soil showed considerably less disease than in non-treated soil. But the reverse situation was also present, i.e., beets had more disease in treated soil than in non-treated. Also, in several flats the difference in disease of beets grown in treated and non-treated portions of soil was not significant. In general it is quite evident that treatment of soil with Arasan had some beneficial effect in controlling seedling disease of sugar beets.

3. Effect of nitrogenous fertilizers on the infection of beets with Rhizoctonia.

Hills and Axtell (1),[8] in their experiments with fertilization of sugar beets with various forms of nitrogen (sodium nitrate, calcium nitrate, ammonium sulphate, uramon and ammonium nitrate), reported that there were no significant differences in beet yield, sugar production and sucrose concentration due to the type of nitrogen used. But there was a relation of various forms of nitrogen to the incidence of dry-rot canker of sugar beets caused by rhizoctonia. Their results show that the smallest incidence of rhizoctonia was in beets fertilized with calcium nitrate and the highest in those fertilized with sodium nitrate. Beets grown in check plots had the highest incidence of rhizoctonia.

The effect of the above-mentioned forms of nitrogen, and in addition a mixture composed of one-half sodium nitrate and one-half ammonium sulphate, was studied on seedling diseases of sugar beets in a soil highly infected with rhizoctonia.

Two series of eight-inch pots were used in this test. To each pot of one series only the nitrogenous fertilizers, calculated on the basis of 0.65 gr. of nitrogen were added. To the other series, in addition to nitrogenous fertilizers, 3.55 gr. of treble superphosphate were also added. Twenty-five seeds were planted in each pot of soil and the experiment was run in duplicate.

The results of these experiments showed that the highest amount of disease in both plantings occurred in soil fertilized with sodium nitrate and T.S.P. At the same time beets fertilized in the second experiment with sodium nitrate alone had a low amount of disease. The occurrence of smaller amounts of disease varied considerably in both plantings. Beets grown in check soil of the second planting had the highest amount of disease. In general, it was very difficult to establish any relationship between the type of nitrogen applied and the amount of disease shown by the beet plants.

Testing beet varieties for their resistance to Rhizoctonia

It has been mentioned that beets grown in one of the fields at the Huntley Station in 1949 were severely infected with rhizoctonia and most of them died before harvest. At harvest time the remaining beets were examined and those free of infection were harvested. These beets were

[8] Numbers in parentheses refer to literature cited.

planted in the greenhouse in Bozeman and ten of them produced seeds. These new varieties of beets were identified M-1 to M-10.

In order to determine whether these beets had any resistance to rhizoctonia, an experiment was conducted to test them and also two commercial varieties (U. S. 22 and 268, and 304R) separately to three cultures of rhizoctonia isolated from diseased beets. Huntley soil was distributed in greenhouse flats and the following plan for this test was adopted:

	Flats used No.
1. Soil disinfected (chloropicrin) and inoculated. Cultures of Rhizoctonia used	
R-1	4
R-2	4
R-3	4
2. Soil disinfected (chloropicrin) and non-inoculated	4
3. Soil non-disinfected and non-inoculated	4

In each flat of soil three rows of beets were planted so that in a unit of four flats 12 beet varieties were planted. Twenty whole or forty disinfected (N. I. Ceresan), segmented beet seeds were planted in each row. Beets were grown for six weeks.

The amount of disease was high for all strains of rhizoctonia used and for all varieties of beets. The percentage of disease was well above 75 percent for all beet varieties, with the exception of M-5 and M-8 grown in soil inoculated with R-1. Variable amounts of disease were present in disinfected and non-inoculated soil. Beets grown in some of the flats were free of disease; in others they had a high degree of disease, and in some only a trace of disease was present. It appears that either chloropicrin did not disinfect the soil completely or it became contaminated after disinfection.

Beets grown in non-disinfected and non-inoculated soil also had a high degree of disease, although slightly lower than those in inoculated soil. None of the varieties tested showed any general resistance to rhizoctonia. In spite of a high percentage of disease a few of the beets grown in these flats remained free of disease, which gave a supposition that it is possible they may carry resistance to rhizoctonia. For this reason 13 healthy beet seedlings grown in soil inoculated with R-2, which showed the highest incidence of disease, were transplanted in individual pots and left in the greenhouse for seed production.

After all beets were harvested, each of the four soil flats was planted separately with the following crops: potatoes, Great Northern beans, Perfection peas and radishes. The reason for this test was to find out whether these strains of rhizoctonia were also pathogenic to some other crops besides beets. All these crops were grown in these flats for two months.

Only one potato plant out of 15 became infected with rhizoctonia. Beans had a slight amount of disease in the soil inoculated with R-1, and a moderate amount in soils inoculated with two other strains. Radishes grown in soils inoculated with strains 2 and 3 had a high amount of disease and a moderate amount in soil inoculated with strain 1. Peas had a high

amount of disease in all soils. These strains of rhizoctonia were practically non-pathogenic to potatoes, moderately so to beans, and highly pathogenic to radishes and peas. The check soils had only a small amount of disease.

Field Experiments

During the summers of 1950 and 1951 the following experiments were conducted at Huntley Branch Station:

1. Effect of fungicides on the infection of beets with Rhizoctonia.

In treating the soil the following five chemicals were used at the rate of 3 pounds per acre in 1950 and 4 and 5 pounds in 1951: Arasan (tetramethylthiuram disulphide), Thiram (tetramethylthiuram disulphide), Ceresan M (ethyl mercury P- Toluene), borax (sodium borate), and Phygon 2,3-dichloro, 1,4-naphthoquinone). Check was also used. The amounts of chemicals used were prorated on a basis of linear feet of sugar beets planted per acre.

Triplicated, randomized plots of soil consisting of two 26.2-feet-long rows of beets were used for each treatment. The whole test in 1950 was duplicated by using two different lots of seeds: a commercial (G.W. 268 and U. S. 22) and G.W.-304R. In 1951 only G.W.-304R was used. Sugar beets were planted with a commercial planter. The required amounts of chemical, mixed with sand, were evenly distributed on the top of the soil in approximately 4-inch-wide strips over the planted seeds. Those strips were lightly cultivated to incorporate the applied chemical into the upper inch of soil.

Readings for seedling diseases were made before thinning. Several readings for Rhizoctonia disease were also made during the summer and fall.

The results of these experiments show that soil treatments with the above-mentioned chemicals had very little effect either on the control of seedling diseases of sugar beets or on subsequent root rot of older beets.

Effect of nitrogenous fertilizers on the infection of beets with Rhizoctonia

Sodium nitrate, ammonium sulphate, uramon, calcium nitrate and ammonium nitrate were used in this test. Each fertilizer was applied to three randomized plots of soil consisting of four 26.2-feet-long rows of beets. All fertilizers were used on a basis of 50 pounds of nitrogen per acre, and were applied on the top of planted beet rows. The rows were slightly cultivated to incorporate the fertilizer.

The amount of seedling diseases varied between 25.8 percent (am. nitrate) and 37.9 percent (am. sulphate). Readings for rhizoctonia disease were also made several times during the summer and they showed that smallest amounts of root rot occurred in plots fertilized with sodium nitrate (34.3 percent). Beets grown in the plots of remaining treatments and in the check had approximately the same amount of root rot (50.3 to 61.4 percent.

Testing beet varieties for their resistance to Rhizoctonia

In the summer of 1950 seven varieties of beets were tested at the Huntley Station for their resistance to rhizoctonia. Five of these varieties

were developed in Colorado and Nebraska, and, as reported, carried some resistance to rhizoctonia. These varieties, and also G.W. Co. 304R, were sent us by R. R. Wood of the Great Western Sugar Company. A local commercial variety of beets was also included in this test. Each variety was planted in two rows 272 feet long. The results of the performance of these varieties were as follows:

Sugar beet variety Name and number	Occurrence of disease percent
G.W. Co. - 208	42.0
G.W. Co. - 526	52.3
A - 1130	55.6
B - 116	52.9
B - 525	71.0
U. S. 22 and 268	57.3
G.W. Co. - 304-R	31.3

These results show that there was the smallest amount of rhizoctonia in 304R and in 208, and the highest in B-525. The remaining varieties showed approvimately the same amount of disease. It appears that none of these varieties showed significant resistance to rhizoctonia.

In the spring of 1951, 37 varieties of beets were again tested at Huntley Station. Eleven of these varieties were sent us by R. R. Wood (they originally came from the USDA, Great Western Sugar Company and American Crystal Sugar Company), and 16 varieties came from Dr. F. V. Owen and Dr. V. F. Savitsky from the U. S. Sugar Plant Field Laboratory in Salt Lake City, Utah. Ten varieties of beets were produced in Montana. The amount of seed of these varieties varied considerably, and for this reason all beet varieties, No. 1 to No. 27, inclusive, were planted in four randomized rows and the remaining 10 varieties in two rows. Regular stand counts and records of diseased beets were made during the growing season and final readings were taken at harvest time when 26.2-foot rows of beets were dug in each replication and roots were examined for the disease.

Table 1 presents the results of this test. Although all these varieties were susceptible to rhizoctonia, the percent and degree of infection varied considerably. In grading for disease, beet roots were divided into two groups, those which had rot and those which had only surface infection. The rot type of disease was considered of greatest importance. Varieties 27 and 37 showed no rot and the number of other varieties (12, 23, 32, 35) also had very little rot-type of infection. Slight surface infection produced very little damage to beets. Severe surface infection was not very prevalent, and only varieties 20, 21 and 25 had a considerable amount of this type of disease. A number of beet roots were harvested from the varieties which showed the smallest amount of disease with the purpose of producing seeds from these beets.

Present plans include expansion of the work of testing varieties of beets for their resistance to rhizoctonia. These tests are in progress now in which 48 varieties of beets are being tested in the greenhouse for their resistance to rhizoctonia, aphanomyces and fusarium wilt. For these tests soils are used in which the maximum of certain types of diseases occur under field conditions. In addition to this a sufficient amount of inoculum is being added to these soils to increase the degree of infection.

Table 1.—Testing Sugar Beet Varieties for Their Resistance to Rhizoctonia Root Rot, Huntley Station, Montana, 1951.

Beet	Variety Name	Theor stand[1] per-cent	Percent Rhizoctonia: Total: Healthy %	Total: Diseased %	Total: Root rot %	Type of disease: Surface infection: Slight %	Type of disease: Surface infection: Severe %	Yield per acre tons	Top to Root ratio: Tops %	Top to Root ratio: Roots %
1	US 1170, GW A 126	89.7	52.2	47.8	16.8	25.6	5.4	13.6	41.9	58.1
2	US 1173, GW A 127	98.5	67.0	33.0	20.8	10.2	2.0	14.6	41.2	58.8
3	US 1177, GW A 123	87.8	61.7	38.3	12.3	24.9	1.1	12.7	41.1	58.9
4	AM CR 9-6040, GW A1150	100.4	68.7	31.3	13.6	15.7	2.0	13.4	44.1	55.9
5	AM CR 0-403, GW A1151	92.4	59.9	40.1	16.4	19.6	4.1	11.7	38.5	61.5
6	AM CR 0-404, GW A1152	79.4	70.2	29.8	9.9	17.6	2.3	12.4	35.9	64.1
7	GW B-525, Sel 526	88.9	58.5	41.5	15.3	23.1	3.1	15.7	41.8	58.2
8	GW B-579, Sel 304 at Scot	89.7	77.0	23.0	11.5	11.5	0.0	16.8	38.6	61.4
9	B-580, Sel 304 at Hunt	80.2	70.1	29.9	13.0	14.3	2.6	12.4	39.7	60.3
10	GW, 304-508	82.1	75.9	24.1	8.8	12.7	2.6	10.7	42.4	57.6
11	GW 359	95.4	67.8	32.2	13.0	17.2	2.0	15.6	37.2	62.8
12	Owen, 944H1	88.9	78.6	21.4	5.8	14.7	0.9	12.3	34.4	65.6
13	Owen, US 22/3, 96	95.4	76.4	23.6	13.4	10.2	0.0	13.3	39.0	61.0
14	Owen, US 35/2, 024	87.8	63.6	36.4	14.7	19.2	2.5	9.7	43.0	57.0
15	Owen, R&G, old type	85.9	48.6	51.4	25.6	22.5	3.3	13.1	33.5	66.5
16	Owen 9090H4	83.2	63.6	36.4	19.4	13.6	3.4	12.0	33.2	66.8
17	Owen 92H1	90.8	74.5	25.5	19.1	6.4	0.0	15.7	35.8	64.2
18	Savitsky 0521	68.7	50.4	49.6	13.3	28.0	8.3	7.6	40.4	59.6
19	Savitsky 0521-24	84.0	45.0	55.0	13.6	34.3	7.1	9.9	39.6	60.4
20	Savitsky 0529-2-9	73.7	28.4	71.6	26.3	34.4	10.9	6.9	41.5	58.5
21	Savitsky 0531-2-6	79.4	43.7	56.3	23.1	23.2	10.0	11.5	35.0	65.0
22	Savitsky 0531-2-5	87.0	63.0	37.0	17.0	15.5	4.5	13.7	37.0	63.0
23	Savitsky 0532-11-4	105.0	67.6	32.4	5.8	25.0	1.6	15.5	45.4	54.6
24	Savitsky 0532-1-3	99.2	68.8	31.2	14.9	14.3	2.0	14.6	47.0	53.0
25	Owen-Savitsky SLC	74.4	23.4	76.6	1..5	51.5	12.6	3.5	52.3	47.7
26	Owen-Savitsky SL-0062	40.1	53.1	46.9	15.2	31.7	0.0	3.1	48.4	51.6
27	Owen-Savitsky 9090M1	68.7	90.0	10.0	0.0	10.0	0.0	7.7	36.2	63.8
28	M-1	67.9	67.4	32.6	9.0	23.6	0.0	13.8	51.3	48.7
29	M-2	70.6	68.1	31.9	9.2	22.7	0.0	20.9	45.8	54.2
30	M-3	84.0	69.2	30.8	12.5	18.3	0.0	16.8	54.3	45.7
31	M-4	93.5	81.6	18.4	10.5	7.9	0.0	20.1	47.0	53.0
32	M-5	95.4	84.6	15.4	6.2	9.2	0.0	12.6	44.2	55.8
33	M-6	95.4	80.0	20.0	18.0	2.0	0.0	18.8	50.0	50.0
34	M-7	74.4	77.1	22.9	12.9	10.0	0.0	9.9	43.2	56.8
35	M-8	80.2	77.3	22.7	5.0	17.7	0.0	13.8	39.4	60.6
36	M-9	97.3	91.9	8.1	8.1	0.0	0.0	12.3	42.7	57.3
37	M-10	90.1	86.4	13.6	0.0	13.6	0.0	19.0	53.3	46.7

[1] On basis of 100 beets per 100 foot of row. Rows 20 inches apart.

Conclusion

The results of all the field and greenhouse experiments in which various nutrients and soil fungicides were used for controlling rhizoctonia disease of sugar beets were largely negative.

Varieties of beets tested for their resistance in rhizoctonia showed a considerable variation in respect to this disease.

Literature Cited

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The Effects of Preceding Crops and Nutrients on the Growth and Seedling Diseases of Sugar Beets in Montana[1]

H. E. Morris and M. M. Afanasiev[2]

Earlier tests in the field and greenhouse indicated that preceding crops varied considerably in their effects on the amount of seedling diseases occurring in sugar beets. In general the amounts of disease were low following oats and corn, intermediate following beans and potatoes, and high following beets, alfalfa and fallow.

The object of the present investigation was to determine the effects on the growth and diseases of sugar beets of most of the important crops usually preceding sugar beets in Montana.

The land at the Huntley Branch Station used for this experiment was manured at the rate of 12 tons per acre and plowed in the fall of 1943. Beans were planted in 1944, but the yield was low due to severe hail damage early in the season.

The crops planted in 1945 were alfalfa (two plots), beans, corn, oats, potatoes and sugar beets. Summer fallow was included to compare it with the crops. Each crop was grown continuously on the same plot (1/4 acre) for five years to fix its effect upon the soil. The average yield of these crops for the five years were: alfalfa 5.47 and 5.11 tons, beans 1,277 pounds, corn 60.4 bushels, oats 78.4 bushels, potatoes 268.3 bushels, sugar beets 13.4 tons (the average yield for 1945, 1946 and 1947 was 16.3 tons and for 1948 and 1949 9.3 tons).

Sugar beets were planted in all of the plots in 1950. The plot five years in summer fallow was also planted. In the fall of 1949, each plot (1/4 acre) was divided into four equal sub-plots. One untreated sub-plot was used as a check, phosphorus (P) 86 pounds P_2O_5 per acre, P and manure (M) 16 tons per acre, and P, M and nitrogen (N) 36 pounds N per acre were added to each of the sub-plots, respectively. The third crop of alfalfa was removed (Alf. R) on one plot, and plowed under (Alf. P) on the other. The crop plowed under was approximately 1½ tons.

In 1951 no amendments were added and all plots were planted to sugar beets to determine the residual effects of the amendments added in 1950.

In 1950 seedling diseases in the 1/4-acre plot (four sub-plots) were lowest in fallow and potatoes (17 percent), and highest in sugar beets (57 percent), and intermediate (25 to 29 percent) in the others. The highest amount of disease occurred in the sub-plot sugar beet PM (71.9 percent) and the lowest in fallow PM (10.6 percent). In 1951 seedling diseases in the 1/4-acre plots varied from 23 (oats) to 33.5 percent (Alfalfa R). The

[1] Contribution from Montana State College Agricultural Experiment Station. Paper No. 259, Journal Series.
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Table 1.—Effect of Preceding Crops on Sugar Beets—1950, 1951, Huntley Branch Station, Huntley, Montana.

	[1] Stand percent		Yield tons		[2] Seedling diseases (%)		Sugar percent		Top-to-root ratio Tops (%)		Roots (%)	
	1950	1951	1950	1951	1950	1951	1950	1951	1950	1951	1950	1951
Oats												
CK	115	92	13.2	11.9	18.3	19.2	16.7	18.4	30.5	36.5	69.5	63.5
P	110	90	14.0	13.6	28.1	21.6	17.3	18.1	33.2	34.6	66.8	65.4
PM	110	99	16.8	15.9	25.3	28.6	16.9	18.3	38.7	38.7	61.3	61.3
PMN	112	97	17.7	17.0	28.3	22.6	17.0	18.2	36.5	42.1	63.5	57.9
Corn												
CK	108	106	13.9	15.2	35.7	41.1	16.2	17.9	43.7	37.9	56.3	62.1
P	108	97	13.9	11.4	20.2	15.1	17.0	18.0	36.0	32.7	64.0	67.3
PM	108	108	19.0	20.0	28.8	24.5	16.9	18.7	43.5	35.1	56.5	64.9
PMN	119	104	18.1	15.7	19.9	25.0	16.9	18.8	47.9	38.1	52.1	61.9
Beans												
CK	98	97	15.9	15.7	34.3	33.3	15.9	18.7	58.9	45.1	41.1	54.9
P	108	115	17.3	17.7	20.9	18.5	15.6	18.4	58.5	41.0	41.5	59.0
PM	98	104	18.4	18.7	30.1	30.9	16.3	17.8	55.0	42.4	45.0	57.6
PMN	102	108	18.5	20.4	29.7	36.1	14.8	18.3	59.0	43.7	41.0	56.3
Potato												
CK	106	105	16.6	15.8	17.2	35.4	16.9	18.7	53.2	36.8	46.8	63.2
P	108	109	18.1	15.4	19.1	33.8	16.5	18.4	51.3	37.2	48.7	62.8
PM	115	100	20.1	16.2	20.9	27.3	17.4	18.1	51.5	38.1	48.5	61.9
PMN	108	103	18.8	17.6	15.4	27.4	17.0	18.8	52.3	38.3	47.7	61.7
Beet												
CK	75	103	8.5	10.9	57.3	44.7	17.6	17.7	44.5	38.6	55.5	61.4
P	94	97	11.5	11.2	44.5	24.7	17.6	17.9	35.2	37.6	64.8	62.4
PM	108	103	14.0	14.2	71.9	23.4	17.4	18.2	37.5	37.0	62.5	63.0
PMN	102	83	16.2	12.3	54.1	13.3	17.8	18.0	38.8	39.6	61.2	60.4
Alfalfa (3rd R)												
CK	106	90	11.2	13.2	31.2	54.9	18.5	.....	41.2	49.0	58.8	51.0
P	102	94	14.8	17.7	23.0	28.6	16.8	18.6	38.2	45.5	61.8	54.5
PM	119	82	16.0	16.7	20.9	36.0	17.3	17.3	48.8	48.9	51.2	51.1
PMN	112	101	17.1	18.3	25.5	14.5	16.3	17.7	52.8	48.4	47.2	51.6
Alfalfa (3rd P)												
CK	94	101	13.6	15.1	28.4	27.6	17.4	17.4	45.2	50.4	54.8	49.6
P	98	86	13.6	16.1	36.5	34.7	17.6	17.9	43.1	47.2	56.9	53.8
PM	98	112	15.5	18.5	18.6	32.1	16.0	17.3	56.1	54.3	43.9	45.7
PMN	110	87	16.0	18.2	26.0	19.7	16.0	17.4	58.3	50.8	41.7	49.2
Fallow												
CK	110	91	16.7	19.5	23.0	31.0	12.9	14.2	71.6	59.9	28.4	40.1
P	108	90	17.3	19.0	15.2	36.4	11.1	13.2	72.4	59.2	27.6	40.8
PM	119	94	20.5	20.2	10.6	17.6	12.6	13.5	70.2	62.8	29.8	37.2
PMN	113	85	18.2	16.2	17.0	11.3	11.9	15.4	72.9	62.8	27.1	37.2

[1] Based on 100 beets in 100-foot row at harvest, rows spaced 20 inches.
[2] Seedling in four to six leaf stage.

highest amount of disease was 54.9 (Alf. R untreated) and the lowest 15.1 percent (corn P).

The yield in 1950 varied from 8.5 (sugar beet untreated) to 20.2 tons (fallow PM), and in 1951 from 10.9 (sugar beet untreated) to 20.4 tons (bean PMN).

In 1950 the maximum production of beets following all crops was in the sub-plot where either PM or PMN was added. Comparing the highest yield of the fertilized sub-plots with the untreated sub-plot in each ¼ acre, the increase varied from 2.6 (beans PMN) to 7.7 tons (sugar beet PMN).

The 7.7 tons represented an increase of 91 percent of the untreated sugar beet sub-plot.

A similar comparison for yield in 1951 varied from 1.8 (potato PMN) to 5.1 tons (Alfalfa R—PMN and oats PMN) or an increase of 39 percent in the alfalfa R sub-plot and 43 percent in the oat PMN.

The results of previous work with sugar beets at the Huntley Branch Station indicate that a proportion of 35 to 40 percent of tops and crowns to 65 to 60 percent of roots at harvest time is satisfactory and usually signifies a balanced fertility of the land. In this investigation the top-to-root ratio exceeded these figures in 1950 in all ¼-acre plots except oats. This would indicate that the season of 1950 was not long enough for the beets to complete their normal development under the specific environment. There was probably an excess of nitrogen which caused increased leaf development and delayed root development.

In 1951 the top-to-root ratio was within the satisfactory zone in the ¼-acre plot of oats, corn, potatoes and sugar beets, and only slightly in excess in the bean plot. The ratio was approximately 50:50 in the alfalfa plots and 60:40 in the fallow. The 1950 yield in general was slightly more than in 1951. The yield results would indicate that a combination of phosphorus and nitrogen was a beneficial amendment for this particular soil. In 1950 and 1951 the sugar percentage was reduced 2 to 4 percent in the fallow ¼-acre plot, but the yield was considerably higher when compared with the beet plot.

Summary

The object of this investigation was to study the effect of preceding crops, alfalfa, bean, corn, oats, potatoes and sugar beets, and summer fallow, on sugar beets. The preceding crops were grown for five years, then the plots were divided into four sub-plots. One sub-plot was used as a check and to the others P, PM and PMN were added, respectively. The following year the residual effects of the amendments were determined. In 1950 seedling diseases varied from 71.9 to 10.6 percent, and in 1951 from 34.9 to 15.1 percent.

The yield in 1950 varied from 8.5 to 20.2 tons, and in 1951 from 10.9 to 20.4. The maximum production occurred where PM or PMN was added, indicating that these amendments were beneficial in this particular soil.

Effect of Temperature on Rate of Rotting of Sugar-Beet Tissue by Two Storage Pathogens[1]

JOHN O. GASKILL AND CARL E. SELISKAR[2]

Species of *Rhizopus* have been reported as causing rotting of commercially stored sugar beets, *Beta vulgaris* L., under certain conditions in Russia (6, 7)[3]. Morochkovsky (6) listed several species associated with sugar beet storage rots and named *R. nigricans* Ehr. in particular as being very destructive at high temperatures. Savitsky (7) also mentioned the genus *Rhizopus* in this connection, indicating that it is pathogenic at 15° to 18° C. (59° to 64° F.).

In the western hemisphere, references to the genus in connection with sugar beet storage rots have been meager. Hodges (3) reported that *R. nigricans* attacked beet roots stored at room temperature, but its relation to commercially stored roots was not clear. As a part of a study of a field root rot of sugar beets, Hildebrand and Koch (2) compared three species of *Rhizopus* for pathogenicity to mother beets planted in compost soil and held at different temperatures. All three species were found to be aggressive pathogens, *R. nigricans* being favored by the lowest temperature (57°-61° F.) of the series and *R. arrhizus* Fischer and *R. oryzae* Went et Pr. Geerligs being most active at the highest temperature level (102-106° F.). These writers suggested the possibility that species of *Rhizopus* constitute a potential threat to stored sugar beets.

Isolates of *Rhizopus* have been obtained in different parts of the United States from sugar-beet storage piles in which rotting had reached the "heating" stage[4], but insofar as the writers are aware, it has not been clearly shown heretofore that *Rhizopus* species actually are directly responsible for rotting in storage piles in this country.

Early in 1951 routine tests for pathogenicity were made with a number of fungus cultures which had been isolated from rotting sugar beets obtained from commercial storage piles in northern Colorado late in 1950. Cultures of a species of *Rhizopus*[5] were among those isolates which were classed as active pathogens on interior tap-root tissue at room temperature. However, at approximately 45° F. this fungus was practically non-pathogenic as compared with others, such as *Botrytis cinerea* Fr. and *Phoma betae* Frank, which were quite active at both temperatures.

A simple experiment was conducted in order to obtain more information regarding the relation of temperature to pathogenicity of *Rhizopus* sp. One culture of this fungus was used, together with a culture of *B. cinerea*, a recognized sugar beet storage pathogen (1, 4, 5, 6, 7), which was included

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[1] Report of a study made under the Research and Marketing Act of 1946. This paper has been approved for publication by the Colorado Agricultural Experiment Station as Scientific Series Article No. 381.

[2] Plant Pathologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, and Assistant Plant Pathologist, Colorado Agricultural Experiment Station, Fort Collins, Colorado, respectively.

[3] Numbers in parentheses refer to literature cited.

[4] A. R. Downie, American Crystal Sugar Co., J. O. Gaskill, U. S. Dept. of Agriculture, and C. E. Seliskar, Colorado Agricultural Experiment Station (unpublished).

[5] After the manuscript had been submitted to the printer, the fungus was identified as *Rhizopus oryzae*.

The 7.7 tons represented an increase of 91 percent of the untreated sugar beet sub-plot.

A similar comparison for yield in 1951 varied from 1.8 (potato PMN) to 5.1 tons (Alfalfa R—PMN and oats PMN) or an increase of 39 percent in the alfalfa R sub-plot and 43 percent in the oat PMN.

The results of previous work with sugar beets at the Huntley Branch Station indicate that a proportion of 35 to 40 percent of tops and crowns to 65 to 60 percent of roots at harvest time is satisfactory and usually signifies a balanced fertility of the land. In this investigation the top-to-root ratio exceeded these figures in 1950 in all ¼-acre plots except oats. This would indicate that the season of 1950 was not long enough for the beets to complete their normal development under the specific environment. There was probably an excess of nitrogen which caused increased leaf development and delayed root development.

In 1951 the top-to-root ratio was within the satisfactory zone in the ¼-acre plot of oats, corn, potatoes and sugar beets, and only slightly in excess in the bean plot. The ratio was approximately 50:50 in the alfalfa plots and 60:40 in the fallow. The 1950 yield in general was slightly more than in 1951. The yield results would indicate that a combination of phosphorus and nitrogen was a beneficial amendment for this particular soil. In 1950 and 1951 the sugar percentage was reduced 2 to 4 percent in the fallow ¼-acre plot, but the yield was considerably higher when compared with the beet plot.

Summary

The object of this investigation was to study the effect of preceding crops, alfalfa, bean, corn, oats, potatoes and sugar beets, and summer fallow, on sugar beets. The preceding crops were grown for five years, then the plots were divided into four sub-plots. One sub-plot was used as a check and to the others P, PM and PMN were added, respectively. The following year the residual effects of the amendments were determined. In 1950 seedling diseases varied from 71.9 to 10.6 percent, and in 1951 from 34.9 to 15.1 percent.

The yield in 1950 varied from 8.5 to 20.2 tons, and in 1951 from 10.9 to 20.4. The maximum production occurred where PM or PMN was added, indicating that these amendments were beneficial in this particular soil.

Effect of Temperature on Rate of Rotting of Sugar-Beet Tissue by Two Storage Pathogens[1]

JOHN O. GASKILL AND CARL E. SELISKAR[2]

Species of *Rhizopus* have been reported as causing rotting of commercially stored sugar beets, *Beta vulgaris* L., under certain conditions in Russia (6, 7)[3]. Morochkovsky (6) listed several species associated with sugar beet storage rots and named *R. nigricans* Ehr. in particular as being very destructive at high temperatures. Savitsky (7) also mentioned the genus *Rhizopus* in this connection, indicating that it is pathogenic at 15° to 18° C. (59° to 64° F.).

In the western hemisphere, references to the genus in connection with sugar beet storage rots have been meager. Hodges (3) reported that *R. nigricans* attacked beet roots stored at room temperature, but its relation to commercially stored roots was not clear. As a part of a study of a field root rot of sugar beets, Hildebrand and Koch (2) compared three species of *Rhizopus* for pathogenicity to mother beets planted in compost soil and held at different temperatures. All three species were found to be aggressive pathogens, *R. nigricans* being favored by the lowest temperature (57°-61° F.) of the series and *R. arrhizus* Fischer and *R. oryzae* Went et Pr. Geerligs being most active at the highest temperature level (102-106° F.). These writers suggested the possibility that species of *Rhizopus* constitute a potential threat to stored sugar beets.

Isolates of *Rhizopus* have been obtained in different parts of the United States from sugar-beet storage piles in which rotting had reached the "heating" stage[4], but insofar as the writers are aware, it has not been clearly shown heretofore that *Rhizopus* species actually are directly responsible for rotting in storage piles in this country.

Early in 1951 routine tests for pathogenicity were made with a number of fungus cultures which had been isolated from rotting sugar beets obtained from commercial storage piles in northern Colorado late in 1950. Cultures of a species of *Rhizopus*[5] were among those isolates which were classed as active pathogens on interior tap-root tissue at room temperature. However, at approximately 45° F. this fungus was practically non-pathogenic as compared with others, such as *Botrytis cinerea* Fr. and *Phoma betae* Frank, which were quite active at both temperatures.

A simple experiment was conducted in order to obtain more information regarding the relation of temperature to pathogenicity of *Rhizopus* sp. One culture of this fungus was used, together with a culture of *B. cinerea*, a recognized sugar beet storage pathogen (1, 4, 5, 6, 7), which was included

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as a standard. Thick transverse slices from sugar beet tap roots were placed in moist chambers, inoculated on the exposed interior surface by means of uniform mycelial discs obtained from agar plates, and held for five to 39 days at three temperatures, together with control slices on which sterile agar discs had been placed in a similar manner. At the end of the storage periods, each slice was sectioned as illustrated in Figure 1, and the depth of rotted tissue was measured. The fungi used were reisolated consistently from the different temperature sets, with the exception of *Rhizopus* sp. at the lowest temperature where no fungus was obtained from tissue plantings. Contamination was found to be negligible in all sets.

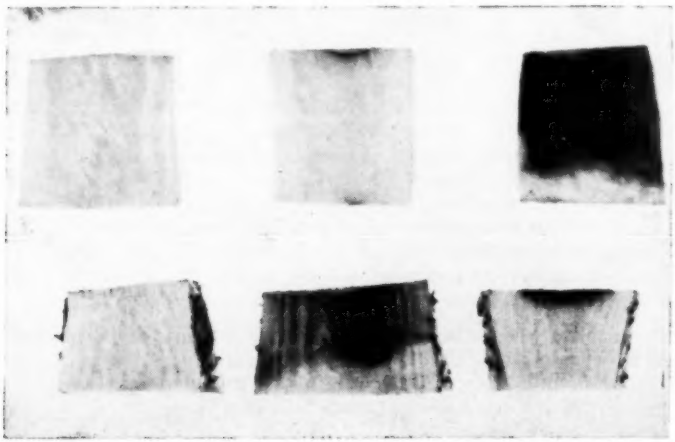

Figure 1. Sections of sugar-beet-root slices showing effect of temperature on rate of rotting by two storage pathogens. Left to right—control, *Rhizopus* sp., and *Botrytis cinerea*. Top—40° F., approximately 39 days. Bottom—83° F., 5 days.

The summarized results (Table 1) indicated that the *Botrytis* culture was active over a wide temperature range, as contrasted with the culture of *Rhizopus*, which was essentially non-pathogenic at 40° F. and extremely aggressive at 83°, where its average rate of rotting was more than four times that of *Botrytis*.

In view of the limited scope of this experiment, the results must be considered with some caution. However, these figures, together with results from the preliminary pathogenicity trials, show conclusively that the species of *Rhizopus* studied is capable of extremely fast rotting of sugar beet tissue at high temperatures and indicate that it is essentially non-pathogenic at temperatures of about 45° F. and below.

From these results it seems probable that the genus *Rhizopus* occupies a relatively important place in the diverse group of pathogens capable of attacking stored sugar beets. Furthermore, since some members of that group—e.g. *P. betae* and *B. cinerea*—are known to be quite pathogenic at

Table 1.—Effect of Temperature on Rate of Rotting of Sugar-Beet Slices by Two Storage Pathogens; Measurements Given as Averages of Three Slices—Two Inoculations Per Slice.

Fungus	Temperature, time, and average depth of rot per day		
	40° F., 39 days	60° F., 14 days	83° F., 5 days
	mm.	mm.	mm.
Rhizopus sp.	0.04	2.2	6.4
Botrytis cinerea	0.9+	1.3	1.4

relatively low temperatures (1, 8), and with the extremely rapid rotting ability of *Rhizopus* sp. at high temperatures, the possibility for a succession of such pathogens with rising temperature is readily apparent. Adding weight to this supposition is the fact that the pathogenic type of *Rhizopus* sp. used in these studies was isolated from five of nine specimens taken from a storage pile at Gilcrest, Colorado—a pile which was being removed for processing because of heating at the time the specimens were collected.

Summary

Pathogenicity of a species of *Rhizopus* isolated from rotting sugar beets taken from a commercial storage pile in northern Colorado was compared with that of *Botrytis cinerea*, a recognized sugar beet storage pathogen.

The average rate of rotting of interior tap root tissue by the latter fungus did not vary greatly over the range of temperatures studied, whereas the average rate for *Rhizopus* sp. varied from a negligible amount at 40° F. to 6.4 mm. per day at 83°—the latter rate being more than four times the corresponding figure for *B. cinerea*.

The results indicate that at least one species of *Rhizopus* probably is a direct cause of rotting in commerically stored sugar beets in the United States when temperatures are relatively high.

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A Study of Two Methods of Testing Individual Sugar-Beet Roots for Resistance to Storage Pathogens[1]

JOHN O. GASKILL[2]

The feasibility of improving storage-rot resistance of sugar beets (*Beta vulgaris* L.) through breeding has been indicated by results presented in other reports (1, 2, 7)[3]

A method described by the author for selecting resistant mother beets (1) involved wound inoculation of the tap roots with composite inoculum, storage for five weeks at 45° F., and subsequent examination for depth of rot by means of a transverse cut through the inoculated area on each root. Those mother beets in which depth of rotted tissue was the least were cut off at the point of examination and transplanted in the field for seed production. This procedure was used on the following tentative assumptions: 1. that many of the more susceptible individuals could be eliminated by examination at the end of the five weeks' storage period; 2. that further elimination of susceptible plants would occur automatically in the field after transplanting, and 3. that, of the surviving individuals, those producing the largest quantities of seed would tend to be the most resistant.

No attempt has been made to confirm these assumptions individually. However, the net result of application of the method in the U. S. 226 variety was substantial improvement in storage-rot resistance (2).

When it is desirable to subject each individual mother beet to various chemical analyses in addition to pure-culture inoculation by more than one storage pathogen, an inoculation technique involving relatively small tissue specimens would be more practicable than the procedure outlined above. In March, 1950, an experiment was begun for the purpose of studying this problem. Six tissue specimens were cut from the mid-region of the tap root of each of 55 comparable mother beets of the wide-base, leaf-spot-resistant variety, U. S. 226, leaving a portion (of crown and tap-root tissue) in condition suitable for seed production. The six specimens were washed in cool tap water and distributed among three incubation chambers, one large and one small specimen in each chamber. Semi-fluid potato-dextrose-agar inoculum was preparted for each of three cultures of storage pathogens—two of *Phoma betae* Frank[4] and one of a species of *Botrytis*[5]. All

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[1] Report of a study made under the Research and Marketing Act of 1946. This paper has been approved for publication by the Colorado Agricultural Experiment Station as Scientific Series Article No. 377.

[2] Plant Pathologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, Fort Collins, Colorado. Acknowledgment is made to the Beet Sugar Development Foundation for facilities and to the Botany and Plant Pathology Section, Colorado Agricultural Experiment Station, for facilities and for two of the fungus cultures used in these investigations; also to Prof. A. G. Clark, Head of Mathematics Department, Colorado A & M College, for advice regarding statistical methods.

[3] Numbers in parentheses refer to literature cited.

[4] Furnished by Dr. Ellis F. Darley, formerly Assistant Plant Pathologist, Botany and Plant Pathology Section, Colorado Agricultural Experiment Station.

[5] After this article had been completed, the latter culture was identified as *Botrytis cinerea* Fr. by Dr. Carl E. Seliskar, Assistant Plant Pathologist, Botany and Plant Pathology Section, Colorado Agricultural Experiment Station.

tissue specimens in each of the three chambers were inoculated with one of the three respective batches of inoculum, as follows (see Figure 1):

1. Large pieces—"interior type" inoculation: A thin transverse slice was removed from each specimen, and two drops of inoculum were placed separately on the freshly exposed surface. Inoculated surfaces were comparable with respect to original position in the tap root.

2. Small pieces—"peeled surface" inoculation: Using an ordinary vegetable peeler, the periderm and underlying tissue were removed to a depth of approximately 1 to 2 mm., and two drops of inoculum were applied separately to the peeled surface.

Figure 1. Incubation chambers, with covers removed, showing sugar-beet root-tissue specimens 27 days after inoculation—interior inoculation method in foreground and peeled-surface method in background. A, *Phoma betae* (culture A-2); B, *Botrytis* sp. (culture 5-1); and C, *P. betae* (culture A-17). The size of the specimens may be visualized by comparison with the width of the chambers (13 inches).

Following inoculation, the specimens were returned to the incubation chambers where they were supported on galvanized wire shelves, over water, for 28 days at 45° F., with relative humidity approximately 100 percent. The chambers were covered loosely. At the end of the 28-day period the depth of discolored tissue beneath each inoculated spot was measured.

The procedure described was used in this experiment in preference to the Russian workers' petri-dish-*Botrytis* technique described by Savitsky (7), partly because of convenience and partly because of the desire to employ a temperature more nearly equivalent to the normal temperature inside commercial storage piles. The use of *Phoma betae* was based on reports of Larmer (5) and others indicating the leading role of that pathogen in causing sugar beet storage rots in the United States. *Botrytis* was included because of its prevalence in earlier storage experiments conducted by the author at Fort Collins and because of the importance of that genus—the *cinerea* type in particular—as a sugar-beet storage pathogen elsewhere, especially in England and Russia (3, 4, 6).

Results

The fungi used for making the inoculations were recovered consistently from representative specimens by means of laboratory platings. Negligible contamination was indicated. The appearance of the specimens at the end of the storage period is illustrated in Figures 1 and 2, and the results are summarized in Table 1. Conclusions of special interest which may be drawn from the interior-inoculation results include the following:

1. Individual roots differed very significantly in average rate of rotting.

2. As shown by correlation figures, roots resistant to one culture tended to be resistant to the others, and vice versa. This was in keeping with results obtained by certain Russian workers, as reported by Savitsky (7). However, the occurrence of definite exceptions to this trend is shown by the very significant interaction, cultures x roots.

3. The *Botrytis* culture was much more virulent than either culture of *Phoma*, the differences in depth of rot being highly significant.

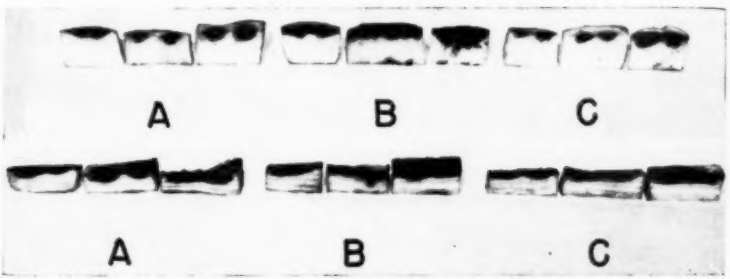

Figure 2. Top—Halves of representative specimens of sugar-beet root tissue showing depth of rot 32 days after inoculation by the interior method: A, *Phoma betae* (culture A-2), three roots; B, *Botrytis* sp. (culture 5-1), three roots; and C, *P. betae* (culture A-17), three roots. Bottom—rot resulting from peeled-surface type of inoculation; otherwise similar to top view. Note differing reaction of individual roots within each group of three (the roots represented by any one group are not necessarily the same as those of any other group).

The average rate of rotting resulting from the peeled-surface method of inoculation was about half that obtained for the interior method. The results from the former were more erratic, as indicated by the higher coefficient of variation, but led to similar conclusions. Positive correlations between the two methods were significant, though exceptions to the general trend are apparent in the table.

From the results presented it seems probable that either of the two techniques described could be used satisfactorily as a means of testing mother-beet roots for storage-rot resistance. The interior method of inoculation was used, with one culture each of *Botrytis* and *P. betae*, for screening several hundred mother beets in the spring of 1950. Progeny tests, now under way, will be used to evaluate the usefulness of this technique.

Table 1.—Depth of Rot in Sugar Beet Tissue Specimens 28 Days After Pure-culture Inoculation; the Specimens Were Held at 45° F. with Relative Humidity Approximately 100 Percent.[1]

Root No.	Interior inoculation Cultures and depth of rot[1]				Peeled-surface inoculation Cultures and depth of rot[1]			
	5-1 (Botrytis)	A-17 (Phoma)	A-2 (Phoma)	Aver.	5-1 (Botrytis)	A-17 (Phoma)	A-2 (Phoma)	Aver.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
1930	14.5	10.5	12.8	12.6	6.5	5.0	6.3	5.9
1931	11.5	10.3	10.3	10.7				
1933	12.0	11.5	15.3	12.9	5.0	1.8	6.8	4.5
1934	10.0	10.0	7.5	9.2	6.5	7.5	4.8	6.3
1935	10.5	8.5	8.5	9.2	5.5	2.5	3.0	3.7
1940	14.0	9.8	8.8	10.8	8.5	4.8	4.5	5.9
1941	9.0	5.8	8.5	7.8	2.3	2.3	3.8	2.8
1942	10.0	9.0	10.5	9.8	5.5	4.0	4.0	4.5
1943	10.0	7.8	8.3	8.7	5.5	3.8	4.0	4.4
1944	15.0	7.5	8.8	10.4	5.0	2.5	2.5	3.3
1945	11.5	8.0	11.0	10.2	7.0	2.0	1.8	3.6
1948	12.5	10.0	7.8	10.1	5.0	4.8	4.3	4.7
1949	14.5	5.3	8.0	9.3	3.0	1.3	3.3	2.5
1951	9.0	7.3	6.8	7.7	4.5	4.8	8.5	5.9
1952	16.0	9.0	10.8	11.9	7.0	2.8	3.3	4.3
1954	12.5	8.3	5.8	8.8	5.0	4.0	6.8	5.3
1955	15.0	9.8	8.5	11.1				
1956	11.0	9.8	8.8	9.8	5.5	2.8	4.5	4.3
1958	13.5	9.3	10.5	11.1				
1962	14.5	9.0	12.5	12.0	10.0	6.5	5.5	7.3
1963	13.0	8.5	10.3	10.6	4.0	4.3	2.8	3.7
1964	14.5	9.5	11.5	11.8	9.0	4.8	3.5	5.8
1965	15.0	4.3	7.3	8.8	7.0	1.8	3.3	4.0
1966	16.0	7.8	9.5	11.1				
1971	13.5	7.8	8.3	9.8	4.0	3.0	4.5	3.8
1972	12.5	9.3	9.8	10.5				
1973	9.5	9.3	10.5	9.8	6.0	4.0	5.0	5.0
1974	12.5	9.0	10.3	10.6	7.0	2.5	4.5	4.7
1976	19.0	10.8	8.3	12.7	9.0	9.5	4.8	7.8

[1] Table 1 continued on page 579.

Summary

Slices from 55 comparable sugar beet roots of the commercial variety U. S. 226 were inoculated in two ways, using two cultures of *Phoma betae* and one of a species of *Botrytis*, and held for 28 days at 45° F. At the end of that period the depth of rotted tissue was measured. Conclusions drawn from inoculation method 1—interior type—included the following: (a) roots differed very significantly in average rate of rotting; (b) roots resistant to one of the three fungus cultures tended to be resistant to the others, and vice versa, though there were definite exceptions; and (c) the *Botrytis* culture was much more virulent than either culture of *P. betae*. Average depth of rotted tissue resulting from method 2—inoculum applied on a peeled surface near the exterior of the tap root—was about half that obtained from the interior method. The results from method 2 were more erratic but led to similar conclusions. Positive correlations between methods were significant, but exceptions to the general trend were apparent.

From the results presented it seems probable that the techniques described are suitable for storage-rot-resistance selection purposes. Confirmation of this tentative conclusion will depend on progeny tests.

Table 1 (Continued)

Root No.	Interior inoculation Cultures and depth of rot[1]				Peeled-surface inoculation Cultures and depth of rot[1]			
	5-1 (Botrytis)	A-17 (Phoma)	A-2 (Phoma)	Aver.	5-1 (Botrytis)	A-17 (Phoma)	A-2 (Phoma)	Aver.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
1977	16.0	9.3	9.8	11.7	9.0	4.5	5.3	6.3
1978	12.5	11.0	9.3	10.9	8.5	4.5	4.3	5.8
1979	13.5	9.3	10.0	10.9	8.0	6.3	3.8	6.0
1981	9.5	6.5	5.8	7.3	7.0	4.0	3.8	4.9
1983	10.5	9.3	7.5	9.1	8.0	4.8	2.5	5.1
1984	13.5	6.3	8.5	9.4				
1985	13.5	6.5	9.3	9.8	2.5	4.5	4.3	3.8
1986	22.0	13.0	9.3	14.8	7.0	4.5	4.3	5.3
1990	9.0	6.5	7.5	7.7				
1991	16.5	12.3	10.0	12.9	6.5	4.0	5.0	5.2
1993	12.5	10.3	8.0	10.3	8.0	5.0	3.5	5.5
1994	10.0	6.8	6.5	7.8	6.5	2.8	4.5	4.6
1997	20.0	14.3	13.0	15.8				
1999	10.0	8.0	9.3	9.1	7.0	4.5	4.8	5.4
2001	10.0	5.5	6.0	7.2	6.0	3.0	2.8	3.9
2006	12.0	7.3	10.0	9.8				
2008	18.5	5.0	14.0	12.5				
2009	10.0	7.8	8.8	8.8	8.5	4.0	4.8	5.8
2010	15.0	12.3	10.3	12.5	9.0	13.0	11.5	11.2
2011	15.5	11.3	10.0	12.3	7.0	3.5	3.8	4.8
2012	12.5	6.8	8.0	9.1	4.0	2.3	1.5	2.6
2039	10.5	8.3	8.8	9.2	7.0	3.5	2.8	4.4
2042	10.5	7.0	5.8	7.8	6.5	3.5	2.0	4.0
2046	12.5	9.0	11.0	10.8	7.0	10.3	3.3	6.8
2054	11.5	7.5	10.5	9.8	6.0	4.0	3.0	4.3
2069	15.0	8.0	9.0	10.7	8.0	5.0	3.8	5.6
Average	12.99	8.66	9.28	10.31	6.45	4.31	4.23	4.99

C. V. (percent)	25.0	42.8
L.S.D.[2] for comparing:		
Culture means	0.69	0.63
Root means	2.9	2.5
F-values for:		
Cultures	90.87**	31.37**
Roots	2.92**	2.94**
Interaction, cultures x roots	3.06**	5.20**
Correlations (r) between cultures:		
Phoma vs. *Phoma*	0.415**	0.509**
Phoma (av.) vs. *Botrytis*	0.480**	0.384**
Correlations (r) between methods of inoculation:		
Phoma (aver.)	0.387**	
Botrytis	0.302*	

[1] Basic data are given as averages of two measurements, each of which was obtained from a different inoculation. In certain specimens inoculated by the "peeled-surface" method, the extent of rotted tissue was such that no accurate measurement could be made. In each such case the root concerned was deleted from the set of results for that type of inoculation.

[2] Five-percent point.

Significance of F and r values:

* = Odds at least 19:1.

** = Odds at least 99:1.

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AGRICULTURAL ENGINEERING

1951 Mechanical Thinning of Sugar Beets at Colorado A & M Gives Encouraging Results[1]

JOHN E. DIXON[2] AND R. D. BARMINGTON[2]

Mechanical thinning tests have been carried on for many years in an effort to get yields comparable to those obtained by hand thinning methods. The test at Colorado A & M College this past year shows no decrease in yield of beets or of sugar from mechanically thinned treatments when compared to the hand thinned check. Furthermore, two mechanically thinned treatments with yields of 16.71 and 16.02 tons per acre respectively had higher yields than the hand thinned treatment which yielded 15.99 tons per acre.

The field for this test was planted at two rates with a John Deere Number 64 planter converted to furrow former openers and "V"-shaped rubber presswheels. Each pass of the planter was one of the five replications of a treatment. However, the crossblock treatment was planted in the form of a block. The two seeding rates were a heavy rate of 9.14 seeds per foot with an average emergence of 39.5 beets per 100 inches and a light rate of 1.91 seed per foot with an emergenc of 10.0 beets per 100 inches. The heavy rate was used for a hand blocked and thinned check and all mechanical thinning treatments, including the crossblocking treatment. The emergence from the light rate was insufficient to carry out the light rate thinning test as planned. This was therefore left as a test of planting to the desired final stand.

Four different machines were used plus the hand blocked and thinned check. All of the machines were followed by long-handled hoe trimming.

The down the row machines used were the converted Eversman blocker, an experimental chain blocker, and the Dixie blocker. For cross blocking the Cultro cultivator was used.

The Eversman blocker was converted to a trial model. Two passes were made over each replication of this treatment. The first pass involved use of a blocking head of twelve 2-inch knives to give 3⅔ inch block centers. The second pass was made with a 24-prong head. This combination means that a prong had to cut into each of the blocks left by the first pass.

The experimental chain blocker is an integrally mounted machine using the chain saw principle. This machine makes cuts at right angle to the row when driven in second gear of the tractor. It gives a much wider latitude for the driver than the other down the row machines. However, there are many problems to overcome in its design. Knives with 3-inch cuts were used with block centers at 5 1/7 inches.

The only ground-driven machine of the four was the Dixie blocker. The blocker heads had 1¾ inch knives and gave block centers of 5⅔ inches in the field.

With the crossblocking treatment it was necessary to remove 75 percent of the original emergence stand. Since the only knives available for the

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Figure 1. The Eversman blocker converted to a trail model showing the blocking knives used.

Figure 2. The experimental chain blocker.

Figure 3. The Dixie blocker.

Figure 4. Crossblocking with the Cultro cultivator.

Table 1.—Results of 1951 Mechanical Thinning Tests.

	Hand Thinned (check)	Eversman Blocker	Chain Blocker	Dixie Blocker	Cultro cross block	Light seeding rate (long handle hoe)	MSD[1] 0.05 (0.01)
Final stand beets per 100 feet	121.0	126.5	113.5	115.0	97.5	70.0	
Tons of roots per acre	15.99	15.62	16.71	15.81	16.02	14.01	2.14 (2.92)
Percent sugar content	13.26	14.70	14.47	13.89	13.18	13.58	1.085 (1.479)
Pounds of sugar per acre	4241	4593	4838	4393	4223	3806	505.7 (689.6)
Percent of check thinning time	100.0	54.58	61.67	72.40	35.98	63.89	
Tons of tops per acre	21.78	20.17	21.05	21.00	20.64	19.48	

[1] The minimum difference for significance at the 0.01 level is shown in parenthesis.

Cultro culltivator varied from 6 to 8½ inches, the corresponding blocks ranged from 1½ to 2⅛ inches. The resulting block center distances of 7½ to 10⅝ inches were larger than the optimum as found from experiments of previous years.

As mentioned previously, the thin planting rate was left as a test of planting to the desired final stand. With this treatment the only work done was with a long handled hoe and this was chiefly for weeding.

In analyzing the results it can be seen from Table 1 that the final stands compare closely to the optimum stand of 100 to 120 beets per 100 feet except the light seeding rate, which is low. As for the tonnage per acre, none of the treatments was significantly different from the hand thinned check. Two mechanically thinned treatments, the Eversman and experimental chain blockers, produced significantly higher percent sugar when compared with the check treatment. None of the treatments was significantly lower in sugar content.

In still another respect, pounds of sugar per acre, the experimental chain blocker treatment was significantly higher than the hand thinned check. A further observation from this table shows that all mechanically thinned treatments required less labor than the hand thinned check.

There is a possibility that the mechanically thinned treatments could have given larger yields if it had been possible to thin them at the same time as the hand thinned treatment was thinned. This thinning was impossible due to wet weather the day after hand thinning was completed.

It is possible to achieve the same beet and sugar yields with mechanical thinning methods as with the hand thinning method. In some cases, as shown by this test, mechanical thinning may even give greater yields of sugar than hand thinning. The hand thinning, however, requires 10 to 15 man hours per acre more than the mechanical thinning. This added cost for labor as well as the problem of securing and managing the labor has influenced the increased use of mechanical thinning methods.

A Report On Tests of Mechanical Weeding and Thinning Equipment in Michigan[1]

GEORGE W. FRENCH[2]

In Michigan and throughout the eastern area mechanization of the sugar beet harvest has progressed much more rapidly than elimination of hand labor in the spring work. However, in 1951 mechanization made some very important advances in this area. For several years prior to 1950 various methods of thinning were experimented with by the beet sugar industry, the Michigan Agricultural Experiment Station, and the United States Department of Agriculture. In 1950, 2.9 percent of the commercial acreage was worked mechanically before hand thinning. In 1951, 26.1 percent of the total acreage was mechanically worked, nearly a tenfold increase over 1950.

Mechanical Thinning Methods and Implements

Two approaches have been made to the problem of mechanized working of sugar beets in the eastern area. One method which has been experimented with is blocking with machines which would theoretically leave undisturbed beet-containing blocks at the desired plant intervals for the final stand and remove all sugar beet plants and weeds between blocks. Several types of blockers have been tested. They may be classified as (a) cross-row and (b) down-the-row blockers. The removal of the plants in spaces between blocks may be accomplished by (a) burning, (b) chemically, or (c) mechanically.

Another approach to mechanization which has been tested extensively is that of random stand reduction. The principle of random thinning differs from blocking in that the removal of plants, including weeds, occurs in several short increments in the length of row equal to the desired plant interval of the final stand. The resulting row strip following random thinning thus will have several possible beet-containing block per foot of row. Several kinds of implements have been used for random thinning. These may be classified as (a) cross row, and (b) down the row. Examples of implements used for cross-row thinning are spike tooth harrows and finger weeders. Down-the-row thinners are machines which have been built specifically for the purpose of sugar beet thinning.

History of Experimental Stand Thinning

A few years ago there was considerable interest in blocking with both cross blockers and down-the-row machines. Irwin[3] reported, on tests conducted in 1946, that yields from the machine-blocked plots were equal to the hand-thinned plots. However, the labor requirements were not appreciably reduced on the mechanically-blocked plots and nearly as much time was spent on hoeing the machine-blocked plots as was required for blocking, hoeing and thinning the hand-thinned plots.

In 1947 the writer conducted tests with three types of down-the-row machine blockers. They were (a) a flame blocker, (b) a chemical blocker, and (c) a Dixie cotton chopper. These machines were all adjusted to leave

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[1] The study reported in this paper was conductd as a cooperative project of the Michigan Agricultural Experimental Station (Agricultural Enginering Department) and the Bureau of Plant Industry, Soils and Agricultural Engineering (Farm Machinery Division) of the U. S. Department of Agriculture, East Lansing, Michigan.

[2] Associate Agricultural Engineer, United States Department of Agriculure, Bureau of Plant Industry, Soils and Agricultural Engineering, Division of Farm Machinery.

3-inch blocks at 12-inch intervals. In comparing the results with the long handle hoe-thinned checks it was found that there was a reduction of 20 percent in the hand labor on the hoeing of the machine-thinned plots. However, there was an average for all machine-blocked plots of 21 percent fewer beet-containing blocks per 100 feet of row as compared with the hand-thinned plots.

In addition to the blocking tests described above numerous experiments with random thinning methods have been conducted in Michigan and Ohio in the past three years.

In order to accept random thinning it is necessary to revise our concept of final stand requirements. It is necessary to think of the final stand in terms of the number of beets in a given length of row rather than of uniform spacing of beets. It is also necessary for labor to thoroughly understand this principle if the best results are to be obtained from the use of random thinners.

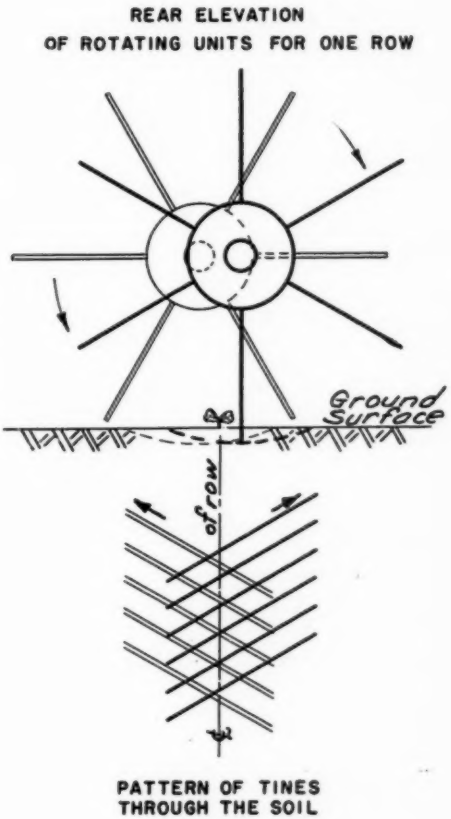

Figure 1. Principle of operation of counter-rotating spring tine thinner. Directions of rotation shown in A. Pattern of scratches across row shown in B. Axes of rotation are parallel to each other and to the row.

Experiments with spacings and doubles have yielded results that support the reliability of random thinning. Frakes (3) in 1946 and 1947 found only slight differences in yields with spacings from 10 inches to 20 inches and that up to 20 percent doubles did not cause any significant reduction in yield. P. A. and H. B. Reeve (4) in 1950 recorded no significant differences in yield in spacings from 10 to 20 inches. Davis (5) in 1950, recorded no differences in yields on muck soil with spacings from 12 inches to 20 inches. However, it was observed that weed growth later in the season was markedly less with the closer spacing. This was apparently due to shading of the ground by the sugar beet leaves. The results obtained in these tests for the effects of spacing and doubles demonstrate that there is considerable latitude without reduction in the yield.

Tests with Experimental Stand Reducer and Weeder

The writer, in 1950, with the cooperation of J. G. Lill[1] conducted mechanical thinning tests using an experimental stand reducer and weeder constructed with two counter-rotating heads on each row. The principle of the counter-rotating heads is shown in Figure 1. A second machine built this year and using the same principle is shown in Figure 2.

The tests reported in Table 1 were made on some plots for variety studies by Mr. Lill. The time required for hand trimming the plots and the yield data were contributed by Mr. Lill.

In 1951 the writer conducted additional tests similar to those reported in Table 1. There were six replications of paired plots planted on May 16, each plot being .0203 acres in area. In this case the beets were worked once

Table 1. Thinning Time After Thinning Stands, Yield, and Number of Marketable Roots of Mechanically Thinned Plots Compared with Plots Thinner and Weeded Entirely by Hand. 1950.

Plot[b]	Thinning Time—Man Hours/Acre	Final Stand Blocks/Acre	Marketable Roots/Acre	Yield Tons/Acre
1-h	—a	—a	28,423	11.402
1-s	—a	—a	24,241	11.892
2-h	32.9	27,027	29,543	12.088
2-s	15.4	21,567	18,818	9.834
3-h	38.8	25,326	24,405	11.075
3-h	38.8	25,326	24,045	11.075
4-h	26.9	25,788	29,543	12.709
4-s	17.5	22,911	23,588	10.781
5-h	33.2	26,775	26,397	12.447
5-s	15.4	18,396	15,551	9.736
Average				
Hand Thinned	33.0	26,229	27,587	11.944
Stand Reduced	16.6	21,021	20,608	10.585
Percent of Check	50.3	83.3	75.0	89.5
	**	*	*	*

*—Significant Difference. **—Highly Significant Difference.
a—Not included in Thinning Time Study.
b—Hand Thinned Only —h.
Machine Thinned Plus Long-handled Hoe Trimming —s.
Note: Time Study on plots .0477 acre in area, yield on .05153 acre plots.
The counter rotating heads were geared to strike the row at intervals of 1.86 inches and at an angle with the row of 44°. The gauge wheels were set for 1" penetration of the tines. The beets were in 4 to 6 leaf stage. These plots were planted on June 18, and machine-thinned on July 11, 1950. Pre-thinning stand counts indicated an average stand of 32 plants per 100 inches of row.

[3] Numbers in parentheses refer to literature cited.
[4] Agronomist, United States Department of Agriculture, Division of Sugar Plant Investigations.

Figure 2. Experimental counter-rotating sugar beet stand reducer. This two-row tractor-mounted unit is power-take-off driven from the tractor engine. Parallelogram linkage and pivot allow adjustment to profile of row and at the same time keep both heads on each row perpendicular. This results in uniform penetration of the tines on both heads. The depth gauge wheel runs directly over the row. Part of the weight of the floating parts is counter-balanced by a spring thus reducing downward force on wheels. The weight (140 lbs.) of floating parts is such that the inertia reduces the tendency to bounce upon encountering hard ground or clods in the row.

with the counter-rotating head experimental machine and then once with a 50 percent thinning head made especially for this experimental thinner. At the time of the first thinning on June 5 the beets were in the four to six leaf stage. The 50 percent thinning head was used 13 days later. The plots were worked with a long-handled hoe in the period June 25-29. The initial pre-thinning stand was about twice as heavy as in the case of plots reported in Table 1. The average stand was 61 beets per 100 inches of row. Only the averages are reported in Table 2.

Discussion of Experimental Results

It will be noted from Tables 1 and 2 that there were substantial savings in labor in both experiments (49.7 percent in 1950 and 30.6 percent in 1951) and there was also some reduction in yield. Part, at least, of the reduction in yield may be attributed to failure on the part of the hand laborer to clearly understand the necessity of leaving some beets closer than the average interval to compensate for gaps.

In both of these tests the hand thinning of the machined plots and also the hand thinning of the check plots was done before the beets reached a size where excessive numbers of plants would result in a diminished rate of

Table 2. Average Thinning Time, Yield and Number of Marketable Beet Roots of Mechanically Thinned Plots Compared with Plots Thinned and Weeded entirely by Hand. 1951. Average of 6 pairs of Plots each .0203 acre in Area.

	Thinning Time Man Hours/Acre	Marketable Roots/Acre	Yield Tons/Acre
Hand Thinned (Check)	21.8	19,800	13.45
Machine Thinned	15.1	14,700	12.50
Machine Thinned (%) Hand Thinned	69.4	74.4	92.55

growth. Had the thinning of both sets of plots been delayed until the competition for plant nutrients and moisture in the unthinned plots was a serious factor it is quite possible that the yields of the unthinned plots would have been reduced more than the yields of the thinned plots.

In both the 1950 and 1951 tests lower yields were recorded for the machine-thinned plots but the yield per man-hour of labor was greater in the case of the machine-thinned plots. On the basis of the 1950 results 98.0 percent more acreage with 74.6 percent greater total tonnage could be produced with a given amount of spring labor when the beets are first mechanically thinned. The corresponding figures for 1951 are 44.0 percent and 25.6 percent. The wide differences in the results obtained on these two different years cannot be entirely explained. It is to be noted, however, from a comparison of Tables 1 and 2 that the man-hours per acre and the man-hours per ton were both lower in the 1951 tests. It was observed that the individual who did the hand thinning on the plots in the 1951 tests was an unusually efficient worker.

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Note: In addition to the references listed it should be noted that several other individuals in the eastern area have conducted equally valuable experiments related to mechanical thinning.

ACKNOWLEDGMENT—The author expresses his appreciation to the Farmers and Manufacturers Beet Sugar Association, the sugar companies in the eastern area, and members of the Michigan Agricultural Experiment Station staff who assisted in the collection of data and preparation of the manuscript. George Stafford, U.S.D.A. assistant on this project, participated in the 1951 test reported in this paper.

The Extent of Spring Mechanization in the Eastern Beet Area, 1951

GEORGE W. FRENCH[1]

The prospect of a seriously diminished labor supply for thinning and weeding sugar beets in the spring was an important factor in bringing about a great increase in mechanical thinning of sugar beets in the eastern area in 1951. Through the efforts of the Farmers and Manufacturers Beet Sugar Association and the sugar companies of this area sufficient numbers of 4-row Dixie thinners were made available to supply the demands of the growers. The extent of the use made of these machines is shown in Table 1.

Table 1. Spring Sugar Beet Mechanization—1951, Eastern Area.

Acres Mechanically Worked—1951		21,837.21
% of total Acres Thinned Mechanically—1951		26.3
% of total Acres Thinned Mechanically—1950		2.9
Breakdown of Thinning Weeding Operations, Acres—1951:		
Once over with weeder head	21,717.21	
Twice over with weeder head	8,446.69	
Three times over with weeder head	796.46	
Once over with 50% head	5,267.49	
Once over with 30% head	169.0	
Total Acres, Cumulative Basis		36,396.85
Acres Thinned per Machine, Cumulative Basis		39.25
Acres Thinned per Machine, Once Over Basis		23.5
1950 and Older Machines Used	84	
1951 Dixies Used	845	
Total Machines Used, 1951		929
Number Grower-owned Machines	907	
Number Company-owned Machines	14	
Number Contracts Worked Mechanically		1,561
Average Acres per Contract Mechanized		13.2
Total Acres Custom Worked		2,772
% of Total Acres Worked Mechanically which were done on a Custom Basis		12.7

Through the efforts of the sugar companies, their field men, and the Farmers and Manufacturers Beet Sugar Association a very marked increase in mechanization was achieved in one year. However, the average acreage worked per machine was probably considerably below their capacity for the thinning season. Some of the factors affecting extent of machine use were: (1) more labor available than anticipated, (2) grower inexperienced with mechanical thinning, (3) unfavorable weather in some areas and heavy soils which crusted badly, (4) reduced total acreage, (5) small acreage of many machine owners, (6) limited inclination among machine owners for doing custom work, (7) reluctance of some growers to change traditional methods of hand thinning.

The practice of mechanical stand reduction and weeding of sugar beets will undoubtedly be extended from year to year. In general, the prospect of

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a declining supply of agricultural labor will continue to be an important motivating factor leading to more extensive mechanization. The application of practices which will improve the performance of mechanical thinners will also help. Some practices in that category are: (1) crop rotations for maintenance of good soil structure and fertility, (2) reasonably uniform seed bed, (3) control of weeds in crops in the rotation with sugar beets, (4) planting at a rate to provide a seed segment every inch, (5) use of a drill which will distribute the seed uniformly, (6) working beets early. The spring tine heads can generally be used when beets are in the two to four leaf stage.

Conclusions

1. Mechanization is here to stay. The long term trend of a diminishing supply of agricultural labor is a potent force exerting pressure for more mechanization in all phases of agricultural production.

2. It has been adequately demonstrated that mechanical thinning is a practice which can greatly increase production per man-hour of thinning labor. With a limited supply of labor, the production per man-hour becomes an increasingly important factor when equated with yield per acre.

3. In the eastern area when the ground becomes dry enough in the spring to work it is almost invariably late enough to plant sugar beets. Consequently, with the high capacity tools and tractor power available for seed bed preparation and planting, most of the beets are planted in the space of two or three weeks. This means that most of them are ready to thin within an equally limited time. Since there is far less labor available than would be required to thin all the beets in the area at the optimum growth stage, it is quite probable that the use of thinners can make possible not only a greater acreage but also a higher yield by extending the period for hand trimming. The beets which are subjected to mechanical stand reducing and weeding will not suffer from overcrowding as soon as unthinned beets, and consequently delay in hand trimming the stand is not as serious as in the case of beets not machine worked.

By reducing the hand labor required per acre, more acres can be handled with a given number of workers in a given period. The length of the period for hand trimming can also be extended by using thinning machines when the plants are in an early growth stage. Partial thinning by machine can extend the time before overcrowding becomes serious and could quite conceivably result in greater yields than otherwise would be the case where hand thinning is delayed, as it frequently is by the lack of sufficient labor to work all fields at the proper time.

ACKNOWLEDGMENT—The author expresses his appreciation to the Farmers and Manufacturers Beet Sugar Association, the sugar companies in the eastern area, and members of the Michigan Agricultural Experiment Station staff who assisted in the collection of data and preparation of the manuscript. The writer is especially indebted to Mr. Glenn Larke for supplying data on the commercial application of thinning practices recorded in Table 1.

Experiences with Spring Mechanization

E. P. PATTISON[1]

During 1951 the Holly Sugar Corporation carried out a series of mechanization demonstrations on plots in each of its Rocky Mountain plant districts. This program served two purposes: first, to stimulate further acceptance of spring mechanization by the grower; and, second, to provide an opportunity to study the adaptability of various thinning practices by identical tests under varying conditions in the widely separated areas of the intermountain area. The plots were located at Sidney and Hardin, Montana; Sheridan, Worland and Torrington, Wyoming; Grand Junction and Swink, Colorado.

Methods were chosen which have been used successfully in many of our districts since the introduction of the small knife principle in 1948. We and other sugar companies as well have been obtaining excellent results with the gear-driven Silver G. W. or a similar machine converted to use the two-inch eight spoke Silver knife. In addition to this, we incorporated a ground-driven thinner which had gained wide acceptance in one particular area in 1950 as a labor saver. This machine is known as the B & P weeder wheel, and is a twenty-spoke one inch knife ground-driven device.

Each demonstration comprised four methods of mechanical stand reduction compared to conventional hand thinning on plots averaging five acres. Each treatment was replicated four times or twenty-eight one-quarter acre plots per demonstration.

These tests embraced the following treatments:

Treatment 1 (or check). Conventional short handled hoe thinned.

Treatment 2. Once over with Silver Thinner—two-inch eight-spoke knives followed by long handled hoe trimming.

Treatment 3. Same as number two plus one-inch B&P weeder twenty-spoke wheel plus long handled hoe trimming.

Treatment 4. Twice over with B&P weeder plus long handled hoe trimming.

Treatment 5. B&P weeder for final stand reduction requiring no trimming by long handled hoe.

Processed seed was planted with precision planters at the rate of eight to twelve seeds per foot of row with an average germination stand of thirty-three percent or thirty-three beet-containing inches per one hundred inches of row. Thinning was done as soon as the beets had attained the four-leaf stage. Conventional short hoe thinning was performed at the regular piece work contract rate while long-handled hoe trimming was worked on an hourly basis. The laborers used for the latter work were those who worked treatment number one or the short-handled hoe and had had no previous experience with this method of working beets, but despite their lack of experience were able to effect a considerable saving in man hours. The average man hours required for thinning the short-handled hoe plots were 24.4 hours per acre. Bearing in mind that treatments two, three and four were the long-handled trimmed plots the following man hours were required:

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[1] Mechanization supervisor, Holly Sugar Corporation.

Treatment 2. 17.3
Treatment 3. 14.8
Treatment 4. 13.9
Treatment 5. None

Stand counts from all thinning operations whether requiring labor or not were as follows:

Treatment 1. 95.2
Treatment 2. 87.
Treatment 3. 85.
Treatment 4. 87.5
Treatment 5. 116.5

These figures represent a total number of beet hills per hundred feet of row.

The results were surprisingly consistent despite the wide variance in conditions throughout the area in which these tests were conducted. The returns to the grower, which are of primary importance, were satisfactory in that these returns after deducting labor and harvest costs showed little difference between treatments.

For example, the returns were as follows:

Treatment 1. $139.45
Treatments 2, 3 and 4. A range of $132.45 to $136.65
Treatment 5 (no hoe thinning). $130.47

Yield in tons per acre ranged from 13.8 to 14.4 on the hoe-trimmed plots while the check exceeded these figures by only 3/10 of a ton. In a typical test at Worland, Wyoming, the returns per acre were as follows:

Treatment 1. $130.20
Treatment 2. 132.79
Treatment 3. 125.45
Treatment 4. 124.82
Treatment 5 (or the plots requiring no hand work). $122.00.

In summarizing it might be well to give some pertinent observations regarding the mechanical phase of the operations on which exhaustive studies were made on every aspect of the work. It was definitely proven that the action of the gear-driven thinner established a more definite pattern than that of a ground-driven wheel and that the resulting population showed a direct correlation to the original stand and therefore enabled us to determine what percent of the remaining stand was to be removed, and that the incorporation of the weeder wheel used in conjunction with the two-inch knife even though it did further reduce the stand was not dependable mathematically, in that its action is more or less erratic tending to slide by or avoid reducing clumps containing multiples, this being of no particular benefit to the reduction of the long-handled hoe work used in trimming. Also, in treatment five it was shown that this was definitely the case in that this method is limited to two operations, either with two units mounted on the tool bars of the tractor, each unit working in opposition to the others, or a single unit twice over the same row, simply because once the cuts have been made a definite track or pattern has been established and therefore the wheel follows the guide in much the same manner as water follows a depression in the land.

Results of the stand counts made following the mechanical operations on treatment five showed that the ground-driven one-inch cut wheel removed forty-six percent the first time over. The second time over showed a reduction of beet hills of six and one-half percent while each succeeding operation removed only from one to five percent of the beet hills. After the first operation fifty-three percent beet hills contained single beets, twenty-nine percent contained doubles, eighteen percent contained multiples. Counts following each operation up to six times over showed that the above percentages of reduction of singles, doubles and multiples remained constant. In other words, the action of a ground-driven thinner is definitely limited and cannot be utilized as a tool to be used for complete mechanical thinning practices. However, had the gear-driven machine been used a definite diamond pattern would have resulted, one which could have been depended upon to provide a final stand containing a maximum of single beets and a minimum of doubles and few if any multiples.

Mechanical Thinning on the Campany Farm in the Red River Valley

O. A. Holkesvig[1]

Mechanical harvesting being well established, the remaining hand labor problem rests on our ability to develop methods which will eliminate or substantially reduce our labor requirements for thinning.

Our 13 years experience on the company-operated farm have given a wide range of experience under all conditions. Progress during this period, though not sensational, has been encouraging as results from mechanical thinning have shown returns equal to hand thinning when consideration is given to the reduction in costs.

In analyzing these results, we find that initial stand is the one factor controlling the final results. Until we are reasonably certain that fair to good uniform stands can be produced under almost all conditions, we hesitate to recommend mechanical thinning as a general practice.

This area being entirely dependent on rainfall for its moisture, a timely rain occurring during the planting season has been necessary to produce the required stands. Weed and multiple plants in the blocks are controlled largely by the size of the established block when cross blocking, blocks one to one and one-half inches in width with a 3-inch strip down the row will provide this control. Stands which will permit this size of block and a minimum of 16,000 beet-containing blocks in an acre will assure yields equal to yields from hand thinning and at a substantial reduction in costs.

It is obvious that the problem has been, and will continue to be, the creation of soil conditions which will promote germination under adverse moisture conditions. Results this past season have been encouraging in this respect, as we brought our field to an excellent stand with only .16 inches of rainfall in May. We attributed our success this season first to the very shallow cultivation and the liberal use of the harrow in preparation of the seed bed, second, to the use of a cultro-cultivator mounted on a tractor with the rotor operating ahead of each furrow opener. This permitted the furrow openers to operate at a uniform depth and the fine mulch produced by the rotors made an ideal cover for the seed and maintained, and possibly hastened, capillary action of subsoil moisture. It is to be noted that the planter was equipped with standard furrow openers and press wheels.

The following is the accumulated data covering our 1951 mechanical thinning on the company farm:

Acreage: 34.58.

Crop History: Three-year rotation: 1949—barley, seeded to sweet clover, 1950—sweet clover summer fallowed; 1951—sugar beets.

Seed Bed Preparation: Date May 16—light tillage with field cultivator followed by harrowing 3 times.

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[1] Manager, American Crystal Sugar Company, Moorhead, Minnesota.

Planter Equipment: John Deere No. 66 equipped with standard furrow openers and press wheels, cells size 12/64″, rows spaced 18″ apart. Tractor equipped with cultro-cultivator with rotors spaced to operate ahead of each furrow opener and set at 1½″ depth.

Planting: Date May 17-18: Seed size 7/64″ to 9/64″, rate of seeding 6.7 lbs. per acre. Planter set to plant 1½″ deep. 100 pounds of 0-36-8 fertilizer applied per acre through furrow openers when planting.

Cultivation: First cultivation June 7-8: Cross blocking, cultivator equipped with discs to establish block with cultro rotors between each set of discs, pattern 2-16″ and 5-14″ rows with blocks 1½″ wide.

Second cultivation June 14: With planter row cultro-cultivator attachment.

Third cultivation June 28-29: Right angle to planted row, cultro attachment.

Fourth cultivation July 10-11: With planted row, with duck foot tools.

Stands: The pattern established with 2-16″ and 5-14″ with planter row with of 18″ provides 23,916 potential beet-containing block per acre. After first blocking, 84 percent of blocks contained beets or 20,089 beet-containing blocks. Thirty-five percent of the blocks contained singles, 37 percent contained doubles, and the balance 3 or more plants to a block. This stand permits a severe treatment with finger weeder.

Finger Weeding: First weeding June 13: At right angle to planted row,

4-leaf stage. Second weeding June 20: With the planted row. Third weeding June 21: At right angle to planted row.

Labor: August 10: Hoeing 5.6 hours per acre @ .75 cents per hour—$3.80 per acre. This compares with $17.00 an acre by the cross-cultivated method.

Yield: 11.37 tons per acre. This compared favorably to results obtained from hand thinning, and to the Valley average, which was 11.23 tons beets per acre.

The historic practice in the Red River valley has been a pattern of 18 inches by 18 inches. A closer pattern in the row has been developed to accommodate fields having spotty stands. The development of the mechanical harvester has increased the width of the planter row and the narrower spacing in the row has been necessary to compensate for the wider planter row.

We hesitate to make specific field recommendations on the basis of results of one year, while we do feel that we have a solution to our stand problem in the use of a cultro-cultivator attachment ahead of the planter. Growers, who had the opportunity to observe the operations and results this year, are making plans to try this practice on their own fields.

Results Obtained from Mechanical Thinning of Sugar Beets in the Eastern Area of the United States in 1951

M. G. FRAKES[1]

The number of mechanical thinners used in the sugar beet crop in the eastern area of the United States increased from 96 machines in 1950 to 929 machines in 1951. Nine hundred seven of these thinners were grower-owned. The total acres on which a mechanical thinner was used at least once in 1951 were 21,837 for an average of 23.5 acres per machine. This compares with 4,878 acres in 1950, or an average of 50.8 acres per machine.

The use of the thinner, and the enthusiasm of growers as regards the results obtained from the use of the machine, varied throughout the territory. For example, one fieldman had more than 90 percent of his contracted acres machine-thinned while others had very few. One factory district had 57 percent of the total acreage machine-thinned while other factory districts had less than 10 percent so worked.

One of the primary reasons for variation in the use of the thinner between territories is the attitude of fieldmen and growers and hesitancy in the proper use of the machines. Inexperienced growers and fieldmen became skeptical and frightened after seeing the results of going over a field of very small beets with a mechanical thinner and weeder. A second reason was poor stands and adverse weather conditions at the time of thinning. Many growers are skeptical of a light stand and wish to tear it up and replant and are extremely hesitant about using any mechanical aids in thinning. In some territories there happened to be plenty of labor ready to work when the beets were ready to thin and consequently farmers did not use their thinners when it was desirable to do so.

Some measures which have been taken to correct the above are as follows:

1. Education of fieldmen and growers. It is extremely important that members of a field force be convinced of the value of the machine before it can be expected that they can do a good job of convincing growers that it is profitable to use. It is very difficult to encourage farmers to use the mechanical thinner properly when a skeptical fieldman is supervising his territory.

2. Demonstrations should be held in each territory to show the proper technique and use of the thinners. Holding meetings to discuss the use of thinners, using visual aids and pictures of results obtained in the field all aid in promoting the use of the thinner. However, the most effective means are actual field demonstrations in each territory. Many growers and fieldmen have a "show me" attitude as regards any relatively new practice. We have found that demonstrations showing proper adjustments and use of the machine and the fact that small sugar beets can be covered with dirt and still emerge have aided considerably in abolishing the fears of growers that they will ruin their stand through the use of a thinner. Our tests have demon-

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strated that small sugar beets, in the two- to four-leaf stage, may be covered with as much as one inch of loose dirt and still emerge.

3. Demonstration of the profitable use of the thinner in other crops. The use of the mechanical thinner in beans and corn in our area has been very successful. By demonstrating to a grower that proper use of the machine is valuable in the production of any type of row crop, and that it is not limited to use in sugar beets, we have greatly increased the sale and use of these machines.

4. Publicity of the results from tests conducted in each territory should be made through every medium possible. Growers are more apt to accept and use a practice which is being advocated if it has been successfully used by another grower with whom he is acquainted.

5. A study should be made, and publicity given to, any improvements made to the mechanical thinner or the use of any new type thinner which may be available. In view of our experience in the eastern area, it is felt that emphasis should be placed on thinning and weeding of sugar beets rather than blocking. For this reason, less emphasis was placed on blocking heads and more placed on spring tine weeder heads or units which use small teeth. There have been several machines, employing the use of small teeth for weeding and thinning purposes, used successfully in our area. These include the Silver or Great Western thinner, the Dixie thinner, the Palsgrove thinner and the Powell and Begaman thinning and weeding units.

Other variations in the structure of the thinner which were tested in 1951 are counter-rotating units in which two heads rotating in opposite directions operate on each row. The use of this type of mechanism has been found to be very effective and commercially made units will be demonstrated this year.

Another improvement tested in 1951 and which will be made available for area demonstrations in 1952 is the use of variable speed thinning units. This is a machine driven by a power takeoff in which the speed of the heads can be varied as the machine travels down the row. This can be accomplished by any number of various types of variable speed units placed between the power takeoff drive and the drive to the individual thinner heads.

Where labor is ordinarily paid on a piece rate basis, many growers ask "how do I save any money by using the thinner when the labor obtains the same amount for blocking and thinning?" There are many answers to this question including the fact that weeds are controlled early before causing excessive damage. By stirring up and aerating the soil, blackroot is brought, and kept, under control. Nitrification is stimulated and increased rate of growth is quite noticeable where beets have been worked with the weeder heads at the proper time. The use of the thinner enables labor to cover more acreage in a given period of time while making it possible for them to leave a better stand.

Several tests were run in the eastern area in 1951, all of which indicate there are no differences in yield due to late blocking and thinning if the machine is used at the proper time. Also, several tests were conducted to

show the effects of stand upon yield. It is a common belief among many of our growers and fieldmen that tonnage per acre is materially reduced if only a 75 percent to 80 percent stand is obtained as compared to a 100 percent stand.

Table 1 shows the results from two separate tests conducted in 1951. These and others indicate that no loss in tonnage is suffered, if mechanical thinners are used at the proper stage of growth, even though hand trimming is delayed ten days to two weeks. All tests indicate, however, that if a

Table 1.—Showing the Effect of Delayed Thinning with and without the Use of a Mechanical Thinner.

Michigan Sugar Company—Muck Soil—1951	
Treatment	**Tons/Acre**
1. Hand thin on time	11.1
2. Mech. thin on time, hand thin on time	11.7
3. Mech. thin on time, hand thin 10 days late	11.6
4. Hand thin 10 days late	9.8

Michigan Sugar Company—Clay-loam Soil—1951	
Treatment	**Tons/Acre**
1. Hand thin on time	17.4
2. Mech. thin on time, hand thin on time	17.3
3. Mech. thin on time, hand thin 2 weeks late	16.8
4. Hand thin 2 weeks late	15.7

mechanical thinner is not used such a delay in hand thinning results in a reduced yield. All figures represent an average of four randomized replications.

At the time of blocking and thinning, many growers do not have as thick a stand as is desirable and wish to tear up their fields and either replant to sugar beets or to some other crop. It has been our observation

Table 2.—Showing the Effect on Yield of Sugar Beets from Spacings in the Row Varying from 8 to 48 Inches.

Michigan Sugar Company—Muck Soil—1951		
Spacing in Row	**Beets per 100 Ft.**	**Tons per Acre**
8 in.	138	12.7
10 "	109	12.6
12 "	104	12.9
20 "	60	13.1
32 "	42	11.3
48 "	31	8.9
12 in. Reseed	91	7.8

Michigan Sugar Company—Clay-Loam Soil—1951		
Spacing in Row	**Beets per 100 Ft.**	**Tons per Acre**
8 in.	151	16.6
10 "	115	16.3
12 "	98	15.4
20 "	60	15.8
32 "	36	13.1
48 "	28	13.2
12 in. Reseed	85	10.9

that the greatest majority of fields which are torn up because of so-called poor stands could very profitably be left rather than tearing up and reseeding. We have found through many tests over the past five years that uniform stands ranging from 60 to 150 beets per 100 feet of row do not materially affect yield of sugar beets. Table 2 shows the results of two tests conducted in 1951, giving the effect on the yield of sugar beets from spacings in the row varying from eight (8) to 48 inches. Included in these tests is a treatment in which the plot was torn up at the time of blocking and thinning (four to six-leaf stage) and reseeded, in much the same manner as a grower would if he thought he had too thin a stand to leave. It is interesting to note that in all cases the reseeded beets, blocked and thinned to an approximate 100 percent stand, did not yield as much as the original beets blocked and thinned to 48 inches or a 25 percent stand.

It should be noted that the spacings in table 2 are uniform and may or may not be similar to stands left in which all of the thinning was done by machine with no hand trimming. Table 3 shows the effect on the yield of sugar beets from varying stands obtained from hand thinning, which resulted in uniform spacing, as against varying stands obtained by repeated use of a mechanical thinner with no hand trimming whatever. All subsequent weeding in the mechanically thinned plots was accomplished by pulling the weeds. There was no hoeing in the mechanically thinned plots in this table.

Table 3.—Showing the Effect in Yield of Sugar Beets from Varying Stands Obtained from Hand Thinning (Uniform Spacing) vs. All Mechanical Thinning with no Hand Trimming (Irregular Spacing).

Clay-Loam Soil—1951			
Hand Thinned		All Mechanical	
Beets per 100 Ft.	Tons per Acre	Beets per 100 Ft.	Tons per Acre
151	16.6	200	11.9
115	16.3	164	11.3
98	15.4	150	14.7
60	15.8	120	14.0
36	13.1	75	14.7
28	13.2	73	15.1

It would appear from this, and other tests conducted in the eastern area in 1951, that best results can be obtained by using a mechanical thinner to thin the beets to an approximate final stand and complete the job by hand-trimming. In many cases where nothing but the machine is used, although the proper number of beets per 100 feet of row may be left, they are not spaced uniformly and result in clusters of beets, sometimes three to five in one foot of row. Consequently, it appears that 100 beets per 100 feet of row obtained by hand thinning will not necessarily give the same yield as 100 beets per 100 feet of row obtained by purely mechanical thinning. This again emphasizes the fact that it is desirable to have uniform stands of sugar beets for proper and correct use of the thinner. Also, it is indicated that, where mechanical thinning is practiced, it may be advisable to leave more beets per 100 feet of row than would necessarily be desired if the entire thinning operation was accomplished by hand.

The general acceptance and use of the sugar beet thinner in the eastern area increased more in one year from 1950 to 1951 than did the use of mechanical harvesters over a three-year period from the time they were first introduced commercially in 1944. We are very encouraged with the results obtained and believe that with proper publicity and field demonstrations on sugar beets growing in the field in the various territories we are well on the way toward eliminating a very substantial percentage of the spring labor required in the eastern area. We think that this can be done with benefit to a grower without reducing, and in many cases actually increasing, his yields. We also believe that the use of the machine will save a great many acres which have been torn up in the past due to poor stands, attacks of blackroot or through the inability of labor to work the fields on time.

Planting, Mechanical Thinning and Weeding

LYMAN H. ANDREWS[1]

Except for a few minor changes, the manufacturers of the standard types of beet drills have made no major improvement for precision planting of beet seed in the past thirty-five years.

In our area there has been one notable exception—the development of the Milton drill. Its vertical rotor with a double row of seed cups on the rim discharges seed evenly an inch above the bottom of the seed furrow. Observations in the field of plantings made by this drill the past two years in our area indicate that there are fewer and shorter gaps without seedlings, and less bunching of seed than for any of the other drills used. This is important where mechanical thinning is followed.

In 1950 we disposed of all but two John Deere 4-row drills in our northern district, and purchased at least one 6-row trail-type double rotor Milton drill for each factory district as demonstrators and rental drills. Fourteen Milton drills planted 3,439 acres of beets in 1951. The 6-row drills planted an average of 253 acres each. One drill planted 547 acres, or almost eight percent of the planted acres at that factory.

The moulded rubber V-shaped press wheel insert improved the germination stands when used on the standard makes of press wheel.

Coincident with the development of mechanical thinning, it is imperative that beet drill improvement be speeded up to provide for more precise planting of the various sizes and types of seed found to be most suitable for each area.

Mechanical Thinning

Early in 1949 D. J. Roach, executive vice president of our company, assigned to several members of our agricultural staff the job of developing a machine which would work in wet or dry soils, in thick or thin beet stands, in clean or weedy fields, in small or large beets, and do a satisfactory job of removing excess beets and weeds, while at the same time leaving a good stand of single beets or small bunches requiring no hand or finger thinning. This was a big order because for twenty-five years beet growers, implement manufacturers and sugar company experts had been trying to develop a machine, a tool, or a system for mechanical thinning which would eventually meet these qualifications and be acceptable to growers and laborers.

A measure of the success of this endeavor is evidenced by the fact that in 1950 the first 335 company-owned Great Western 4-row beet thinners and 80 grower-owned machines thinned 29,554 acres mechanically. This past year 52,745 acres, or 30 percent, were thinned by 414 company-owned GW thinners and 54 grower-owned machines in our four state area. Grower and labor acceptance from the first assured a mechanical solution to the problem of hand thinning. It seems to me it is no longer a question of "can it be done?" but rather one of "how soon can it be made universal?"

In the development of the GW beet thinner in 1949 every known tool or machine developed up to that time was tried out on our farm at Windsor,

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[1] Northern District Manager, Great Western Sugar Company.

Colorado, under soil conditions which varied from dry to extremely wet. Beets were mechanically thinned from the two true leaf stage to those whose foliage almost covered the ground and were mixed with weeds 18″ high.

None of the machines, systems or combinations tried out during 1949 did the work under all conditions as well as the Great Western 4-row thinner developed at Windsor.

This system of GW mechanical thinning differs from cross blocking in that the power-driven rotating knives always leave three small blocks with the 8-bladed head and six blocks with the 16-bladed head in each foot of row, whereas the usual cross blocker left only one block of greater width in each foot of row. These smaller blocks contained largely single plants requiring no finger thinning from the labor. When the 16-tooth cutter head equipped with 5/8″, 3/4″ or 1″ knives is used, six small blocks of approximately 1″ in width are left per foot of row, and the stand is reduced 35, 50 and 57 percent, respectively, from that of the original.

The GW thinner is a rugged 4 or 6-row machine which travels down the row. It has a simply designed adjustment in the hub of the wheel for quick changing to span four or six rows of 20″, 22″ or 24″ row widths. In a matter of minutes it can be adjusted for wide and narrow row combinations by sliding the individual thinner units to the proper location on the drive axle. The 8-bladed cutter heads revolving at right angles to the direction of the rows leave a block of beets every 3½″. They are easily and quickly removed for exchange to a different set of longer or shorter knives to leave the kind of stand desired. Since the cutter heads rotate across the rows, it will thin properly when the thinner is off to one side of the row as much as 2″ to 3″. It is mounted on rubber and powered by its own traction, permitting it to be pulled behind any row-crop tractor by simply hooking it to the draw bar. It has a one-lever control for all rows, but each row is able by the use of compression springs to work independently and thereby insure that the cutting knives will operate at the desired depth in the soil at all times.

Each machine to be adaptable to most all types of stands should be equipped with at least three sets of cutting heads, viz., 1½″ and 1¾″ for the 8-blade heads, and the third set of, preferably, 5/8″ knives on 16-blade heads. The latter type is generally used the second time to complete the mechanical thinning process known as the Windsor or "Twice-Over System."

The "Once-Over System"

Most of the acreage thinned so far by the GW thinners has been by the "Once-Over system," which is quite simple. It consists of selecting the proper cutting head to leave approximately twice the number of plants desired for a final harvested stand. When the germination stands are reduced to this point, beet labor has a better opportunity for selecting the single plant, weed-free hills, thus speeding up and improving the quality of its work.

In the heavier germination stands, the 8-blade head with 1¾″ knives will remove 50 percent of the stand, and for stands as light as 20 percent, the smaller knives will do a good safe job. Experience soon demonstrated to growers that poor germination stands could be worked with the machine

without reducing the plant population below that desired. At the same time it will remove some weeds within the row, while mulching the soil with an in-the-row cultivation.

Determining the germination stand is the first step before mechanical thinning. This is done by placing a 100-inch tape along the row to be counted, and counting the inches which contain beets. The number of beet-containing inches becomes the percent germination stand. These may be singles, doubles or multiple plants in each inch. At least ten counts at random, made diagonally across the field, will give a fair estimate of the germination stand. Using Table 1, look down the lefthand column to the figure closest to the stand resulting from your counts; then select the blade indicated which will give the kind of thinned stand desired.

Table 1.—Number of Beet Hills Remaining Per 100 Foot of Row After Using the Cutter Heads Shown Below.

Germination Stand[1]	Once Over System						Twice Over System[2]		
	5/8" 16 Blade	1½" 8 Blade	7/8" 16 Blade	1¾" 8 Blade	1" 16 Blade	2" 8 Blade	1¾" 8 Blade plus 5/8" 16 Blade	1¾" 8 Blade plus 7/8" 16 Blade	1¾" 8 Blade plus 1" 16 Blade
16	132								
18	144	120							
20	156	132	120	120					
22	168	156	132	132	120	120			
24	180	168	144	144	132	132			
26	204	180	156	156	132	132	96		
28	216	192	168	168	144	144	108		
30	228	204	180	180	156	156	120		
32	252	216	192	192	168	168	120	96	
34		228	204	204	180	180	132	108	
36		252	216	216	192	192	132	120	
38			228	228	192	192	144	120	96
40			240	240	204	204	156	132	108
42			252	252	216	216	156	132	108
44					228	228	168	144	120
46					240	240	180	144	120
48					252	252	180	156	132
50							192	168	132

[1] Beet-containing inches in 100 inches of row.
[2] The 8-bladed head followed in 4 days with the 16 bladed head shown.

Once Over 5/8" 16-Blade Head will cut out 36% of Beets
1½" 8-Blade Head will cut out 43% of Beets
7/8" 16-Blade Head will cut out 50% of Beets
1¾" 8-Blade Head will cut out 50% of Beets
1" 16-Blade Head will cut out 57% of Beets
2" 16-Blade Head will cut out 57% of Beets
Twice Over 1¾" 8-Blade Head plus 5/8" 16-Blade Head will cut out 68% of Beets
1¾" 8-Blade Head plus 7/8" 16-Blade Head will cut out 73% of Beets
1¾" 8-Blade Head plus 1" 16-Blade Head will cut out 79% of Beets

For example, with the 8-blade heads there are three choices with knives 1½" and 1¾" and 2" in length, and three choices with the 16-blade heads with the 5/8", 7/8" or 1" knives. Assume we have a 26 percent germination stand, by using the 5/8" 16-blade head (1st column) the GW thinner would leave 204 hills per 100 feet, or by using a 1½" 8-blade head (2nd column) it would leave 180 hills in each 100 feet. This stand is approximately double the number of plants required for an average of one beet per foot at harvest time, and is recommended as the kind of stand to leave for hand labor to

finish. Examination of the figures below the chart will disclose that either the 7/8" 16-blade head or the 1¾" 8-blade head will remove 50 percent of the stand. Also, the 1" 16-blade head or the 2" 8-blade head will reduce the germination stand 57 percent.

Ordinarily the 8-blade heads are preferred for the "Once-Over" thinning method; however, the 16-blade heads leave twice as many bunches only one-half the width of those left by the 8-blade head. Conditions must be more favorable for its use as it has a greater tendency to cover small beets and is rougher on the tops of large plants.

It is recommended for growers not acquainted with the use of the machine to start out with the "Once-Over Method" and leave plenty of stand. This is not too serious where hand labor is following to complete the mechanical thinning operation.

If the beets are small and are apt to be severely damaged by dashing rains, hail or wind storms, it is best to use the type of thinner head which will leave double the number of beets desired until they are larger, when the stand can be reduced a second time over with the thinner.

Complete Mechanical Thining—"Twice-Over Method"

This system requires the use of the 8-blade head first, followed by a 16-blade head for the second operation four to eight days after the first time over. If, for illustration, the grower used a 1¾" 8-blade head on a 30 percent germination stand followed in four to eight days by a 5/8" 16-blade head, he would have 120 beet-containing hills per 100 feet of row, with approximately 15 to 25 as doubles or multiples.

Since the small knives pass through the row of beets at a slight angle, it is important that the two operations go in opposite directions. This makes a criss-cross pattern which cuts out most of the weeds in the row. The blocks left are small squares in the center of the beet row containing a large proportion of singles with fewer weeds than if the second operation had followed the same direction as the first. Going over the field twice gives two in-the-row cultivations which are better for the crop than two ordinary cultivations.

In 1950 our company on its Windsor, Colorado, farm completely mechanically thinned (without any finger thinning) 294 acres of sugar beets at a savings of 56 percent of the summer work without loss in yield. The total hand labor bill for hoeing and weeding was $10.35 per acre, a saving of $12.15 from the regular contract price of $22.50 per acre. This work was again repeated on 251.1 acres on the same farm in 1951. Mexican National labor used for the hoeing was paid 80 cents per hour for all but one field, which was at $5.50 per acre. The average cost for hoeing was $7.24 per acre. The hoeing was delayed until after June 20th when most workers had finished their thinning.

A number of beet growers throughout the Great Western territory this past season tried out the Windsor "Twice-Over Method" on their entire contract. Several attained yields as high as the highest in their communities at a great saving in labor and at reduced costs for hoeing and weeding.

Company's Plan for Using the GW Thinner

Our company decided to loan the machines to the growers without cost, since only a few would purchase them until workers were convinced they could earn more money per day at reduced rates following machine work, and until beet growers recognized the system was successful.

As a further inducement, wherever the machine was used a credit of $1.50 per acre was allowed up to an amount which would offset a labor charge of $2.00 per acre on those farms where workers were shipped to the grower at company expense for transportation. Under this arrangement in 1950, the company machines thinned an average of 81 acres per machine, or approximately three times the average of 28 acres for the grower machines. In 1951, the company machines' average was increased to 121 acres, while that for the grower was 46 acres per machine, still approximately one-third that of the company machines.

The 79 additional 6-row machines introduced in 1951 proved so popular that 144 of the 4-row thinners were exchanged for a like number of 6-row machines for use in 1952. The maximum thinned last year by a 4-row thinner was 303 acres, as compared to 491 acres by a 6-row machine. Many of the 4-row machines thinned over 200 acres, and a large number of the 6-row machines thinned more than 300 acres for the season. One of our Lyman, Nebraska, growers thinned 42 acres in 7½ hours with a 4-row machine. The present number of company thinners has a potential ability to thin mechanically 100,000 acres in 1952.

The control of the machines was the responsibility of the company fieldmen. The number of machines assigned to each fieldman was in proportion to the acreage of his district. All other field work was made secondary to the operation of the thinning machines. To assist the fieldmen during the thinning season the receiving station repair crews were used to help adjust the machines and stay with them until the work was going satisfacorily. This allowed the fieldmen more time to manage the placement of his machines.

Each grower was urged to visit his neighbor's field from whom he was to get the machine, to learn how to operate and adjust it and be ready to move it to his farm as soon as it finished. Growers were requested to tell the fieldmen in advance when they would finish with the machine, or when they would be ready for one. A daily report was made by each fieldman to his manager of the acreage covered by each machine.

Field demonstrations for growers on the earliest plantings and during the summer months on specially planted plots were found to be very helpful in showing the method and advantages of mechanical thinning. Some beets should be mechanically thinned with the machine at the demonstration plot three to four days before the day of the demonstration. This provides an effective comparison between the recovered beets and those being thinned.

The first demonstrations held should be for the company's agricultural staff to learn the technique and to become sold on the method.

In 1950 after the first extensive trial with the GW thinners, a survey was made of 483 growers who had used them. Nine out of ten of these

growers favored the use of the machine. An analysis of their replies gave the following observations:

> No loss in tonnage resulted through use of the machine. Many indicated an increase in yield following mechanical thinning because of an increase in stands over hand thinning. The timely use of the thinner cuts out excess plants and weeds, conserves moisture and fertilizer, and prevents loss of tonnage from delayed thinning. It is not necessary to have thick germination stands, as the machine is easily adjusted to work thin stands of beets. It takes the place of regular cultivations, in addition to cultivating in between plants in the row. Large acreages can be thinned daily with the machines. It assists workers in making larger hourly earnings and increased seasonal earnings because they have a longer time in which to work. The "Twice Over Method" eliminates the need for finger thinning. The workers are needed for only the hoeing and weeding. Using the GW thinners balances mechanical harvesting.
>
> A limited use of the spring tine heads on the GW thinner when used after thinning promises to eliminate small weeds and grass without injuring the beets. This operation following complete mechanical thinning shows promise of reducing most of the hoeing and weeding. Under present conditions, migrant laborers will not remain in beet-growing areas for late hoeing and weeding.

I am not so naive as to believe that the system or machine I have described is the final solution. I know that both will be improved with time and by experience. This is the way of progress. It is not an easy job. I invite and urge every one here to concentrate on improving the technique and expanding the method to include every beet grower in every area. The success or failure of the program is largely in the hands of our agricultural force.

In conclusion, I want to congratulate the entire Great Western agricultural staff for its tireless, resourceful and enthusiastic salesmanship responsible for introducing in so short a time, on such a large scale, a method which promises to restore the growing of sugar beets to its former place in the agricultural economy of the West.

Technique of Coloring Sugar Beet Seed for Treatment Identification

L. A. KLOOR[1]

In the treating of processed sugar beet seed, advantage was first taken of the usefulness of a water-soluble dye by adding a small amount of it to a suspension of the treating materials which were applied as a spray to the sugar beet seed. Thus used, the dye served as an infallible telltale of the quality of coverage, mechanically attained, by the spray treating equipment (1)[2]. Opportunity was afforded, also, to make some studies of the comparative effectiveness of fungicides which, when sprayed on the irregular surfaces of sugar beet seed, resulted in light, medium and heavy coverage with the treating material.

Early in 1948 some preliminary experimental work was done with dyes to determine the practicability of their use for the identification of specific seed treatments. In this search for satisfactory dyes, the range was purposely limited to the three primary colors—red, green, and blue, since it was contemplated that only three kinds of seed treatments would be made available for sugar beet growers—namely, insecticide, fungicide, and a combined insecticide-fungicide treatment. Pigments were not given serious consideration since they are not water soluble. It was felt that insoluble pigments would only add to the volume of the suspended materials used in the treating "mix," thereby increasing the chances of difficulty with the seed treater spray nozzle.

The natural color and the absorbent character of the tissue which composes the decorticated sugar beet seedball make it an ideal base for the application of red, green, blue and yellow dyes. Even seed from processed lots which contained a high percentage of dark colored seedballs responded to dyes, particularly the green.

In making the final selection of the dyes which were to be used commercially in conjunction with seed treatment, a group of each of the primary colors mentioned, and yellows, were tested. Since any coloring media selected had to be applied as a component part of the spray "mix," these dyes were screened on a basis of (1) complete compatibility with the fungicide Phygon and the insecticide Lindane, or, with combinations of both; (2) solubility in water; (3) brilliance without the use of excessive dosage; (4) freedom from phytotoxic effects upon germinating seed; (5) color-fastness for at least twelve months when seed was stored in paper bags; and (6) cost per pound.

In the process of elimination, three dyes were found which met all of the requirements stated and gave satisfactory results. The red selected was Safranine A, concentration 147 percent; the green was Victoria Green WB; and the blue was Methylene Blue 2B. It was found in commercial practice that the green and the blue dyes imparted colors to the beet seed which, because of lack of sufficient contrast, were confusing. The use of blue was discontinued and a yellow substituted therefore. The yellow selected was Auramine O, concentration 130 percent. The enthusiasm with which most of our growers have accepted our method of identifying sugar beet seed treatments by color has led to its permanent adoption as part of our process-

[1] Research Agriculturist, Holly Sugar Corporation, Stockton, Calif.
[2] Numbers in parentheses refer to literature cited.

ing procedure. From the beginning, we have used a red dye to identify sugar beet seed which has been treated with Lindane insecticide only. There is little or no demand for this single treatment. Yellow dye is used to identify seed which has been treated with Phygon fungicide only. In all of our beet producing areas where wireworms are not a factor this seed treatment is recommended and is generally accepted. The choice of a yellow color was a fortunate one for this treatment, since it intensifies the light yellow cast which treatment with this fungicide gives to the seedball. Moreover, when seed which has been single-treated with Phygon is returned from our early planting areas we find it a simple procedure to add the proper dosage of Lindane by retreatment for reissue to growers planting in wireworm-infested areas. The green dye, which is used to identify the double-treatment with Phygon and Lindane, when superimposed upon the yellow color, completely effaces that color.

Three grams of any one of the aforementioned concentrated dyes were found to give a satisfactory color to the processed sugar beet seed when applied in two quarts of treating material per hundredweight of seed (2). When we first started using dyes, the procedure was to dissolve 132 grams of dye of the appropriate color in 2 gallons of hot water. When cooled, this dye solution was added to the treatment "mix" prior to its completion to a predetermined volume of 22 gallons. A total of 44 hundredweight of seed was treated with this volume of treating materials. Because of the time consumed in the dissolving and cooling of water solutions of dyes, the method was modified. We now make up concentrated stock solutions of the dyes to be used in alcohol. Generally, 5 gallons of solution are made at a time. Each pint of concentrated solution contains 132 grams of dye. The concentrated solution to be used for any desired quantity of treating materials is measured and diluted with cold water prior to being added to the treating materials. Thorough agitation is given the "mix" during the addition of dye solution.

Agriculturists, fieldmen and growers have accepted the value of seed treatment and have come to look upon color-coding the specific kind of treatment as a necessary adjunct thereto. The psychology of being able to see that seed has been treated is quite effective and cannot be ignored. At least three west coast processors now color their processed treated sugar beet seed for purposes of treatment identification. One of these is seriously considering the use of color identification of specific varieties. One producer-processor of flower seed uses dyes for the coloring of the seed to indicate the color of the flower which will be produced. It is evident that the possibilities have not been fully exploited.

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Soil Row Treatment at Planting Time

AUSTIN A. ARMER[1]

The application of massive doses of fungicides to the soil surrounding the planting zone of crop seeds is a procedure of proved merit.

L. D. Leach and W. C. Snyder (1)[2] have published results of studies on localized chemical applications to the soil and their effect upon root rots of beans and peas.

Hildebrand, McKeen and Koch (2) have demonstrated the effectiveness of fungicide applications in the planted sugar beet row in amounts ranging from 2 to 5 pounds per acre.

Their work in soil row treatment, both in the greenhouse and in the field, demonstrated effective control of black root under conditions where ordinary seed treatments were not effective.

The protection of the growing root system of a beet seedling is self-evidently greater when fungicide is distributed throughout the root zone than when the fungicide is applied only as a seed treatment. In the latter case, the protected zone is limited to a region of about ½ inch from the center of the seed. Such protection will usually suffice to bring about emergence, but post-emergence damping-off occurs when the root system continues its growth into infected soil.

In continuing their field trials with beans and peas, Leach and Snyder first used a five-gallon can of fungicide solution mounted on the planter and feeding by gravity to a sprinkler head placed over the row. In their later work, they used a specially constructed trailer behind the planter comprising a 50-gallon solution tank, a ground-powered gear pump and a nozzle directing the fungicide spray into the planted row.

Figure 1. The soil row treater in the field. Because of the very short hitch points on the device, steering and trailing of the planters are not affected.

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[1] Agricultural Engineer, Spreckels Sugar Company.
[2] Numbers in parentheses refer to literature cited.

Figure 2. Experimental device for spraying massive doses of fungicide into the soil at planting time. Pumps are driven from the ground wheels, one supplying spray pressure, the other agitation of the matrial in the tank.

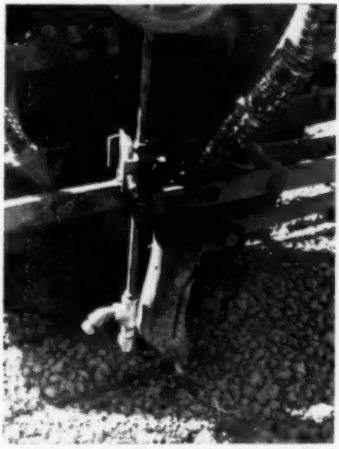

Figure 3. Fungicide is applied to the row directly behind the planter opener by two nozzles. The first wets the sides of the furrow at the instant of seed drop and the second sprays the covering soil.

When the Spreckels Sugar Company undertook a series of experiments on soil row treatment in 1950, the equipment was designed with the guidance and counsel of Dr. L. D. Leach and full advantage was taken of the pioneer work which he had done.

The mechanism as finally developed was a refinement of the equipment used by Dr. Leach which had been constructed by the Agricultural Engineering Division Research Laboratories, University of California. The Spreckels-built unit had the following characteristics:

1. A two wheel chassis which straddled the planter tongue.
2. A hitch which was adjustable vertically to match different tractors to different planters.
3. A chain and gear train from each rubber-tired ground wheel to a separate gear pump.
4. Suitable connections from one gear pump to carry fungicide liquid under pressure to a manifold with gage and pressure regulator.
5. Hose connections accommodating from 2 to 6 duplex nozzles.
6. Adjustably mounted pairs of nozzles behind each furrow opener.
7. Connections from the second gear pump to the fungicide tank for producing continued agitation.

The duplex nozzles were arranged in such manner that the forward nozzle projected a spray of fungicide onto the walls of the furrow immediately after the seed was dropped, but before any appreciable amount of soil had fallen back into the furrow. The second nozzle was directed so as to project

a fan of spray in the plane of the planted row. This had the effect of wetting the particles of soil as they fell back into the furrow.

The use of these duplex nozzles effectively surrounded the seed zone with fungicide liquid so that more or less uniform distribution of the active material was realized for a distance of 1½ to 2½ inches from the center of the seed.

The machine as described proved convenient and versatile. Not only could it be used for fungicide placement but also for the application of starter fertilizers designed to accelerate seedling growth. A third possibility yet to be investigated is the application of flocculating substances as a means for preventing crust formation.

The uses of the soil row treatment equipment as above described are discussed at length in a paper entitled "The Effect of Certain Soil Row Treatments on Damping-off of Sugar Beet Seedling Growing by Specific Fungicide" by L. D. Leach and F. J. Hills.

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A Seed Metering Device for Planting Experimental Plots

C. E. Cormany and Wayne Baker[1]

The Holly metering device for planting short row test plots, developed in 1945, offers excellent seed distribution in the rows and reduces labor costs more than one-half.

This device is held to the frame of many types of commercial beet drills by bolts. It does not affect the handling of the beet drill in any way. It can be adapted for 1, 2, 3, 4 or 6-row width of plots.

Briefly, it consists of a fluted roller built into a small seed hopper, the roller being turned by hand through the seed as the drill moves forward in the field. The seed is conveyed by tubes to the openings of the drill shoes, or discs, and is covered by the beet drill.

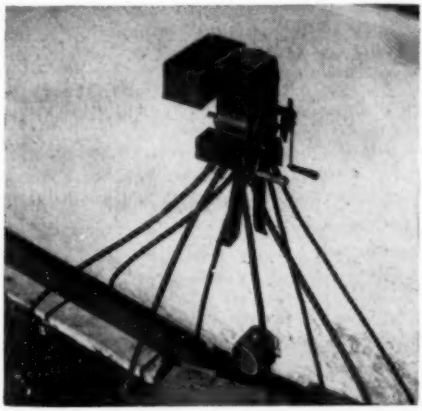

Figure 1. A unit for planting plots 4 rows wide. For more details address the authors.

The operator stands upon a platform held in place by angle irons fastened to the rear of the beet drill frame.

The exact amount of seed required for each plot is placed in envelopes. These are placed in consecutive order in a compartment attached to the seedhopper. Seed of the individual plot is poured from the envelope into the hopper. The operator turns the feed roller by hand as the drill moves forward. Very little practice before starting the actual plot planting is necessary to establish proper speed of turn. Seed remaining in the hopper at the end of the plot is turned out. The fluted roller is brushed with a wire brush after each plot is planted to insure against seed mixtures.

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[1] Chief Agronomist and Research Assistant respectively, Experiment Station, Holly Sugar Corporation, Sheridan, Wyoming.

A Progress Report of Planter Tests in Michigan[1]

GEORGE W. FRENCH[2]

The work reported on in this paper is a continuation of mechanical planter tests reported in 1951. (1)[3] A number of different furrow openers, press wheels, seedbed preparation devices and forces on the press wheels have been tested. Three of the more promising press wheels and experimental furrow opener are shown in Figures 1 and 2.

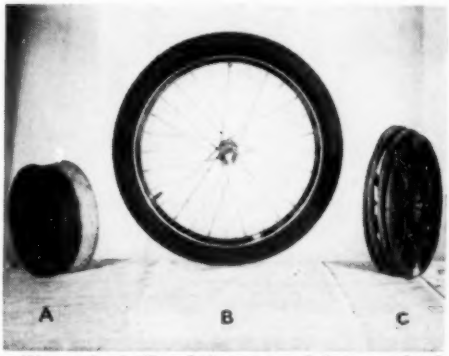

Figure 1. A. Beveled commercial press wheel. B. 2.125 x 20 pneumatic-tired bicycle wheel. C. Four section press wheel.

The two outside sections of the press wheel C in Figure 1 are rigidly fastened to a hub which in turn fits on a closely fitted spindle or axle. The two outside sections are 12 inches in diameter. The two inside sections are 12½ inches and 12¾ inches in diameter and have center holes which fit loosely over the hub to which the outside sections are firmly fixed. The center holes of the inside sections are of such a diameter that when all sections are resting on a plane surface the hub is in contact with the lowest point on the circumference of the holes in the two center sections.

Spacers, 7/16-inch thick, are used between sections. The two center sections are free to turn independently of each other and the two outside sections. Slightly different diameters result in different angular velocities between any two adjacent sections.

The action of the wheel was such that there was no difficulty from soil filling in between the four sections and producing the effect of a solid wheel.

Carleton (2) tested a pneumatic press wheel and the rolling wheel furrow opener (Figure 2, B) in 1947 and 1948 with some encouraging results. The writer (1) continued testing these components in 1949 and introduced the four-section press wheel (Figure 1, C) that year. In 1949 and 1950 various combinations of press wheels, furrow openers, and downward forces on the press wheels were tested. The results of the 1949 and 1950 tests which are summarized below were reported in detail in 1951 (1).

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[1] The study reported in this paper is being conducted as a cooperative project of the Michigan Agricultural Experiment Station (Agricultural Engineering Department cooperating) and the Bureau of Plant Industry, Soils, and Agricultural Engineering (Farm Machinery Division), U. S. Department of Agriculture.

[2] Associate Agricultural Engineer, Bureau of Plant Industry, Soils, and Agricultural Engineering (Farm Machinery Division), U. S. Department of Agriculture, East Lansing, Michigan.

[3] Numbers in parentheses refer to literature cited.

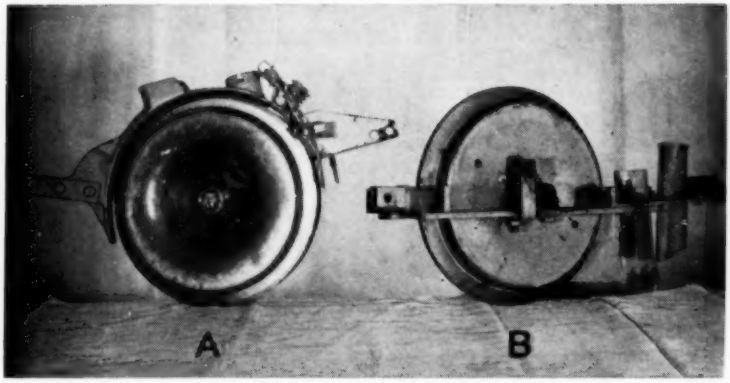

Figure 2. A. Commercial double disc furrow opener with depth bands to provide for 1-inch planting depth. B. Experimental rolling wheel furrow former equipped with depth bands to provide for 1-inch planting depth. The close fitting shoe back of the wheel served to keep the furrow open until the seed dropped to the bottom of the furrow. The thickness of the wheel at the periphery is ⅜-inch, at the depth band, ¾-inch.

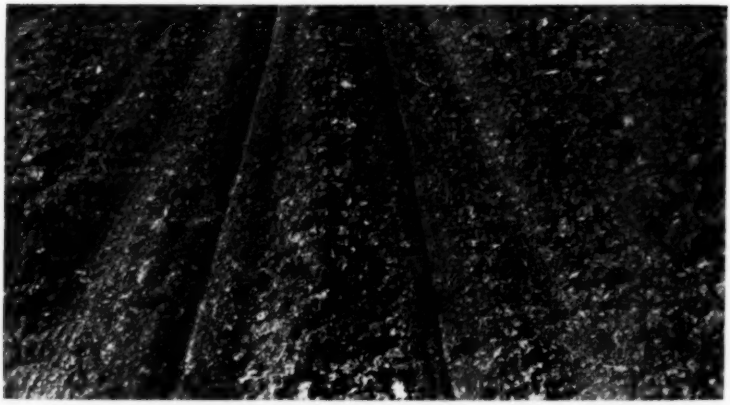

Figure 3. Appearance of seedbed following row strip seedbed preparation and planting. The two rows in the center were subjected to this experimental method of seedbed preparation. The outside rows were planted on a conventional seedbed. The coarser clods can be seen in the centers between the rows.

Figure 4. Unit for grading aggregates left in row strip and compaction of row strip.

Summary of Results

1949-1950

1. In 1949 the rolling wheel furrow opener showed promise of producing better emergence than the commercial double disc furrow opener used with the commercial beveled press wheel. In 1950 no significant results could be attributed to furrow openers alone.

2. In 1950 significant interactions between furrow openers and press wheels were indicated. Of the six furrow opener — press wheel combinations used, two appeared to be better than the others. The double disc commercial furrow opener (Figure 2, A) with the experimental four-section press wheel (Figure 1, C) was consistently associated with comparatively high emergence rates. This was also true of the rolling wheel furrow former (Figure 2, B) and commercial beveled press wheel (Figure 1, A) combination.

3. In 1949 and 1950 the double disc furrow opener—beveled press wheel combination was associated with comparatively low rates of emergence.

4. No consistent effects from downward forces on the press wheels ranging from 55 pounds to 155 pounds were recorded.

Results of 1951 Tests

In 1951 the press wheels (Figure 1) and the furrow openers (Figure 2) used in 1950 were again tested. Since no consistent effects from downward forces on the press wheels were observed in previous years, that variable was discarded and seedbed preparation substituted as a third variable.

A conventional seedbed was prepared by plowing, tandem disking, and dragging with a spring tooth harrow. An experimental seedbed was prepared in rows by grading the soil aggregates and moving the coarser clods to the centers between the rows (Figure 3). The refinement of the seedbed in the row strip was accomplished as follows:

1. After plowing and tandem disking, disc hillers mounted on the tool bars of the tractor were used to throw up ridges of soil approximately six

inches high and a foot wide at the base. The spacing between the ridges was equal to the spacing between the beet rows to be subsequently planted.

2. The purpose of the ridges was to provide an excess of soil over the row strip so that removal of clods would not leave a depression. The equipment for separating out the coarse clods is shown in Figure 4. When used with a trailed planter this operation and planting was accomplished in a single pass through the field.

The unit A in Figure 4 is power-take-off driven in reverse to direction of travel. It is centered over the strip where the row is subsequently planted.

Table 1.—Percentage of Potential Emergence and Least Significant Differences Attained in Experimental Planting Made On May 16, 1951.

Stand Counts June 4. Potential Emergence = 100%					
Main Effects					
Seed Bed	**Percent**	**Furrow Opener**	**Percent**	**Press Wheel**	**Percent**
C	43.3	DD	42.1	BW	40.4
E	47.7	RW	48.9	PN	45.0
				4S	51.1
		Least Significant Differences			
	3.32*		4.42**		5.43**
First Order Interactions					
Seedbed x Fur. Opener	**Percent**	**Seedbed x Press Wheel**	**Percent**	**Furrow Opener x Press Wheel**	**Percent**
E x RW	54.2	E x 4S	55.0	RW x 4S	51.6
E x DD	41.1	E x PN	49.6	RW x PN	43.8
C x RW	43.8	E x BW	38.1	RW x BW	51.4
C x DD	42.9	C x 4S	47.0	DD x 4S	50.5
		C x PN	40.2	DD x PN	46.2
		C v BW	42.5	DD x BW	29.3
		Least Significant Differences			
	6.25**		7.67**		5.79*

C—Conventional seedbed
E—Experimental seedbed
DD—Double disc furrow opener
RW—Rolling wheel furrow former
BW—Beveled press wheel
PN—Pneumatic press wheel
4S—4-Section press wheel
*—95% level of significance
**—99% level of significance

On May 16, 1951, a planting was made using six combination of the three press wheels and two furrow openers (Figures 1 and 2) which were used in 1950. These furrow opener-press wheel combinations were used both on the conventional seedbed and the experimental row strip seedbed and replicated eight times. A factorial experimental design was used so interactions between press wheel, seedbed, and furrow opener could be evaluated. An analysis of variance on results of stand counts made on June 4 indicated significance in respect to both main effects and interactions. The results are shown in Table 1.

Discussion of the Results

The experimental seed bed preparation in rows produced significantly better results than the conventional seed bed.

Soil moisture at time of planting and precipitation afterward are factors which may overshadow the effects of the furrow opener and presswheel. The more striking contrasts were obtained in 1949 on a planting made on a dry, cloddy seedbed. The rolling wheel furrow former (Figure 2B) produced markedly superior emergence. In 1950 precipitation of 2.3 inches occurred a few hours after making a planting. All treatments produced low emergence rates with no significant differences. In 1951 the emergence with all treatments was much higher than the same ones in 1950.

Summary of Results

1. The four-section presswheel—commercial double disc furrow opener and the beveled presswheel—rolling wheel furrow former combinations have produced emergence superior to that attained with the commercial presswheel—furrow opener combination. Consistently improved emergence cannot be attributed to the furrow opener alone.

2. Superior emergence was associated with a high degree of seedbed refinement in 1951.

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ACKNOWLEDGMENT—The author expresses his appreciation to the Farmers and Manufacturers Beet Sugar Association, the Michigan Sugar Company, and members of the Farm Crops, Soils and Agricultural Engineering Departments who assisted in the collection of field data, analysis of results, and preparation of manuscript.

Custom Harvesting in California

C. C. O'Hara[1]

While the title of this article is "Custom Harvesting in California," actually it will deal with conditions in the South San Joaquin valley, south coastal area, and Imperial valley.

Mechanical harvesting of sugar beets came into rather general use in the above areas in 1945. This was possible because of the heavy purchase of beet harvesters, principally of the Marbeet type, by the various sugar companies, the farmers generally being reluctant to purchase equipment as costly and as untried as were the available harvesters. Another handicap experienced, particularly in areas where beets were grown on beds, was to find farmers with heavy enough tractor power to pull double row harvesters. However, in areas where single row beets were grown that was not the problem, for the average grower could handle a single row harvester with the power he had.

For the next couple of years, a great deal of the mechanical harvesting was done with sugar company-owned machines, rented to the growers. This system was entirely wrong for it put such a terrific burden upon the agricultural forces of the processors that they had little time for any other duties. The machines generally were mistreated, causing terrific upkeep, and the performance per machine was very low.

After the machines had proven themselves capable of doing a satisfactory job, many growers purchased their own machines. It was very noticeable that with growers owning the machines the number of breakdowns was greatly reduced, and deliveries per machine improved accordingly.

It was at this point that custom harvesting entered the picture, and it has filled a very great need in the sugar beet business, in a great portion of our area where double row beets are planted, and which require the 2-row harvester. The grower still lacks the necessary tractor power to satisfactorily pull a 2-row harvester.

The custom harvester is particularly suited to the grower who does not plant sugar beets year in and year out, which type is quite general in some of our areas; also, the smaller grower who could not afford an investment in a harvester for limited yearly operation. The fact that a grower has access to custom harvesting has made the beet crop more attractive to growers who might otherwise plant a crop which could be handled more easily; for instance, if the grower had to rig up a tractor and arrange for trucks, and rent a harvester to pull, or be faced with possible hand labor for harvest, he could very well decide against beets.

The general practice in California is for the custom operator to supply the necessary trucks needed for hauling the beets to a loading station, so that when a grower engages a custom man he has very little to do with the harvest except supervision. The cost to the grower for using this method

[1] Manager, American Crystal Sugar Co., Oxnard, California.

of harvest has been considerably less than by hand; this year's rates running generally at $1.30 per ton of net beets yielding 20 tons per acre. The price varied up and down with the tonnage. This price generally included two pick-up men, where needed.

It has been my observation that the most successful custom operators have been the men using the 2-row machines, because this machine is more adapted to large scale operation, and because of its heavy construction is subject to less breakage; this is important to a custom operator.

There are several large custom operators in California who work the Imperial valley in the spring and then move to the coastal areas or interior valleys for the fall campaign. Some of these operators are running as many as five 2 row machines. Practically all makes of tractors will be found in use pulling harvesters; however, you will find one thing universal amongst custom operators, and that is they will use tractors overpowered rather than under-powered, for their success depends upon plenty of tractor power.

The usual practice is for the operator to make his contracts with the growers well in advance of harvest and arrange for the jobs at that time, then at harvest time take the beets in the order of their maturity.

The factor which makes for the success of a custom operator is that he be allowed to work every day and on a reasonable delivery basis, and to encourage this type of operator we have regulated harvest schedules to accomplish this, feeling that with a very heavy investment in equipment, unless the operator can realize a return on his investment and a fair labor return, he will become dissatisfied with beet harvesting and turn his efforts elsewhere; this could be a big loss to the industry.

One hears of exceptional deliveries made by some operators, but it has been our experience that if a 2-row machine will average 125 to 150 tons per day, and this is 20-ton beets, it has done very well. Possibly, a fair average for Marbeet Jr. and Midgets would be 75 to 100 tons per day.

In conclusion, I would urge all growers who contemplate the use of mechanical harvesters, either their own or that of a custom operator, to exercise some care in land preparation and in the planting, then follow through with clean fields. If the above practices are followed, mechanical harvesting can be most successful.

Performance of Various Makes of Beet Harvesters In American Crystal Areas

GEORGE W. NIXON[1]

The 1951 beet harvest will be recalled as one of the most difficult experienced in American Crystal territory. Continuous rains in California after November 23 curtailed mechanical harvesting. Snow and rain in the intermountain area caused delays and factory slices to be reduced. Snow and freezing weather delayed harvest in the eastern territory and stopped harvest completely at times. In face of the almost universal adverse harvest conditions, a larger percentage of beets was harvested mechanically than in any previous year. Each factory district, without exception, increased the mechanically harvested acreage over previous seasons.

Table 1.—Percentage of Acres Harvested Mechanically in Nine American Crystal Sugar Company Factory Districts.

	Percentage	
California	**1950**	**1951**
Oxnard	66	83.2
Imperial valley	71	97.3
Clarksburg	63.5	83.9
Average	66.3	88.3
Intermountain		
Missoula	78.3	86.5
Rocky Ford	56.2	60.0
Grand Island	55.3	61.9
Average	60.7	65.6
Eastern Territory		
Mason City	61.2	72.7
Chaska	65.9	86.5
Red River valley	48.0	76.6
Average	51.3	77.1
Average American Crytal Territory	56.7%	77.8%

A pronounced shortage of harvest labor has developed in most areas because of increased labor demands for various industries and defense projects.

School requirements for children under 14 years of age does not permit sufficient income to maintain the family. For this reason heads of families are turning to permanent employment in other lines of work.

Growers purchased additional harvesters and neighbors helped each other as they completed their own deliveries. The equipment was pushed to the limit and it was difficult to maintain proper quality of work. After the first snow many of the non-resident workers returned to their homes. It became readily apparent that mechanical harvesters must harvest a large

[1] Agricultural Superintendent, American Crystal Sugar Company, Rocky Ford, Colorado.

portion of the acreage remaining, and it can be said the machines performed the job in a creditable manner despite the many adverse conditions.

The number of beet harvesters operated over a nine-year period in American Crystal Sugar Company territory is as follows:

1943	9	1948	565
1944	36	1949	671
1945	82	1950	943
1946	172	1951	1177
1947	305		

Five makes of harvesters predominate in American Crystal territory, namely Marbeet, International, John Deere, Scott Urschel and King-Wyse.

In California the standard two-row Marbeet leads in quantity performance. Where the new disk topping unit is used, the topping job is equal to most other machines. The Marbeet Midget, however, is the coming machine and is already beginning to replace the two-row machines because of its being more adaptable to smaller farming operations, requiring less manpower, doing good quality work and being more flexible for a controlled harvest.

The intermountain area uses the International machine principally and this machine continues to perform in a satisfactory manner. Spiked wheel Terwilliger top-moving units were added to many machines in those areas where tops are conserved for feed. Picking table devices for removal of clods were used in larger numbers. Parma beaters for removal of hanging petioles and trash were used more extensively on the International machine.

The John Deere No. 54 is used at Grand Island and performed well this year because of the moist condition of the soil. Production for this machine was below the average.

In the eastern territory the International has fast become the leading machine and performed well this fall. The Scott-Urschel machine is used principally at Mason City and Chaska. The new Scott-Urschel equipped with rubber belts is definitely superior to the old chain type. Constant hard freezes deteriorated the foliage and with frozen dirt hanging to the beet it was difficult to pick up the beets and they were dropped back to the ground, resulting in a mediocre job. The King-Wyse machines in the area performed in an excellent manner. The wet condition of the soil prevented a clod situation which would undoubtedly present a problem in dry hard ground as the King-Wyse does not provide for clod removal. A roto-beater operation to remove foliage was often repeated several times ahead of the harvester.

The 56 John Deere 2-row machines released to American Crystal growers this year performed very well for the first year. Increased daily output of this machine appealed to larger growers. Spiked lifter wheels proved to be the outstanding feature. Elimination of clods in heavy dry soil was satisfactory. Quality of topping and disposal of tops are especially liked by growers in feeding areas.

Many John Deere 2-row machines were operated this year to better advantage as two units and had better recovery than the single unit. Growers

Table 2.—Make and Performance of Harvesters in American Crystal Sugar Company Areas.

Make	Number	Acres Harvested	Tons Harvested	Acres Per Unit	Tons Per Unit
Marbeet 2-Row	62	15,108	297,329	243	4,795
Marbeet 1-Row	22	2,988	55,890	135	2,540
Marbeet Midget	45	5,679	108,447	126	2,410
International	781	58,240	662,983	75	850
John Deere 2-Row	56	6,612	73,767	118	1,317
John Deere 54	45	1,690	18,013	37	400
Scott-Urschel	129	6,404	68,473	50	531
King-Wyse	33	3,350	37,096	101	1,124
Harvall	3	213	2,383	71	794
Homemade	1	4	56	4	56
Total	1,177	100,288	1,324,437		
Average				85	1,125

using 2-row John Deere harvesters should plant their fields in the spring with 12 border rows which can be harvested first to provide turning space on the balance of the field.

The machine was well accepted but under the severe harvesting conditions which existed this year weaknesses in construction developed, chiefly in the topping unit and top disposal unit. This was expected during the first year of use and probably will result in favorable changes being made as all 200 machines released commercially last year are being returned to the factory for necessary improvements.

The experimental 1-row John Deere tested out in Colorado last fall has definite possibilities to become one of the outstanding harvest machines because of its high production possibilities and quality work. When this machine will be ready for commercial release, I do not know, but ordinarily it takes several years from an experimental model to a production model.

Manufacturers of harvesting equipment are to be commended for their interest and determination in constantly improving their equipment.

Mechanical harvvesters did their job in 1951 and did it well in the face of bad weather when labor left the fields and refused to work under such conditions. For this reason, growers are fast thinking of "spring mechanization" and total mechanization of the crop.

The Mechanical Harvesting of Beets and Tops in Great Western Territories

JAMES R. MASON[1]

The irrigated farming areas in which the Great Western Sugar Company operates in Montana, Wyoming, Nebraska and Colorado are some of the choice farming areas of the United States. The irrigated farms generally vary from 80 to 160 acres in size and in the main can be classed as "family type farms." Fairly good systems of crop rotation are followed which include beets, potatoes, vegetables, small grains, corn, beans and alfalfa. The average acreage of beets per contract ranges from 22 to 25 acres. A large percentage of farmers have some kind of a livestock feeding or dairy program, both to market the farm products and to create a supply of barnyard manure.

Since the start of beet raising in these areas the beet laborers (hand laborers) have been the source of the farm workers needed to raise the other crops produced, particularly potatoes, beans and the produce crops. It is understandable then why many growers were not too enthusiastic about mechanizing beet raising when they realized that it meant the loss of the labor supply needed for these other crops. This fact probably accounts in part for the fact that some other beet growing areas such as California earlier took the lead in mechanical harvesting. This reluctance to harvest mechanically was also due to the value placed by many growers on beet tops in their livestock operations, and to the feeling that mechanical harvesting meant sizable losses in the beet tops to be recovered.

Another factor was the "insistence of perfection" in harvesting machines when they were first introduced and to comparisons of machine harvesting with the best quality of hand labor which had been available in previous years.

As the supply of labor for harvesting began to be more difficult to secure, and as this fact began to be realized by growers, there was a noticeable increase in the acreage harvested mechanically.

Probably this shortage of harvest labor has been the greatest single factor in the recent rapid growth in mechanical harvesting in Great Western territories. It undoubtedly was the reason why the Great Western districts, such as Montana where the labor supply was most difficult to obtain, took the lead in mechanical harvesting as compared with areas where the harvest labor situation was not quite as critical.

During the last two or three years the shortage of harvest labor has been getting increasingly acute. The demands of the armed services and defense industries have been a large factor in this shortage. Moreover, the competition offered in the harvest of large cotton crops in Texas and other warmer climates reduced the normal carryover of Texas laborers in all beet growing areas. The misunderstandings and the endless troubles, to say nothing of the expense, of the Mexican National programs made that source

[1] Southern District Manager, Great Western Sugar Co.

Table 1.—Summary of Opinions on Various Sugar Beet Harvesters by the Great Western Sugar Company.

Efficiency in Harvesting Beets	International 1,873 machines	JD 2-Row 71 machines	JD 1-Row 660 machines	Marbeet Midget 68 machines	Scott Urschel 164 machines
1. Quality of Topping	fair to good	good	good	fair to good	poor to good
2. No. of beets missed	few (approx. 2%)	High under muddy cond. Breakage causes considerable loss under all conditions	few (appr. 2%)	High under muddy conditions. Require a scavenger. Longer spikes help	High depending on operator and cond. of tops.
3. Dirt Elimination	Too much dirt lifted. Poor without picking table	Poor under muddy cond. Questionable under cloddy cond. Too great a mass of dirt on belt under all cond.	Light friable soil good. Loader principal offender on both trash and dirt.	Good under most cond.	Fair. Cons. trash included with beets
4. Capacity (per day)	2½-3 A. per day.	7 A. per day when running	1½-2½ A. per day	2½-4 A. per day	4 A. ave. per day
5. Mech. Dependability	Good as long as can get traction.	Poor. Machine too heavy but critical parts are too light.	OK on light friable soils. Poor under other cond.	Gen. good as long as they have traction and keep the wheel free of mud	Good under good conditions.

(Table continued next page)

Table 1.—(continued).

Effectiveness of Harvesting Tops

1. Top Disposal	Poor	Fair. Unless care is used tops are run over by trucks.	Good	Fair to poor	Poor
2. Condition of Tops	Poor to fair	Fair to good depending on care exercised	Good	Fair to poor	Poor after trucks run over field.
	International	**JD 2-Row**	**JD 1-Row**	**Marbeet Midget**	**Scott Urschel**
Improvements needed	Take care of tops. Larger tires on cart. Better methods to remove dirt and clods. Improve belt finder. Install beater for mech. thinned beets. Hydraulic snubbers on topper	Strengthen weak parts. Improve dirt elimination. Improve loss by breakage and missed beets. Revise top disposal and topping mechanism	Strengthen mach. including roller chain and good bearings. Use a cart to eliminate loader.	Better dealer service. Longer spikes. Improve top conveyor. Better cleaner on lifting wheel. Better puller points.	Better top disposal. Better topping. Separate trash and clean beets. Use a cart.
Growers' opinions of machines	Not satisfied with top disposal. Don't like excessive dirt and necessity of picking table labor.	Generally disappointed but realize machine worked under bad conditions. Too expensive. Costly to operate in men and trucks because of breakdowns.	Opinions mixed. Growers like topping and top conservation. Main supporters are on light soil and small contracts. Other growers consider machine obsolete. 166 not used in past season.	Generally good. Dislike loss of beets. Adaptable to various tractors. Low labor requirements. Machine shows promise.	A few growers like it while others term it a fair weather machine. It is difficult to operate and adjust. It is useless after hard freezes.

of harvest labor unsatisfactory with growers. Under these circumstances it is indeed fortunate that the harvesting machines have been developed to the point where they could take over the harvest load. Without them, it is doubtful that enough labor could have been secured for the 1950 and 1951 harvests.

That the growth of mechanical harvesting in Great Western territories has been very rapid in recent years is shown by the following:

Year	Acres Harvested	% of Acreage Harvested Mech.
1946	17,924	8.98
1947	46,718	21.00
1948	63,504	44.17
1949	78,639	50.13
1950	119,902	59.51
1951	132,978	76.71

This rapid increase in mechanical harvesting resulted in a very strong demand on the part of growers for harvesting machines. Dealers were able to quickly dispose of allotments of machines from manufacturers and many arranged for the transfer of additional supplies from other beet growing areas where the demand was not so acute. Some growers went many hundreds of miles to purchase used machines and brought them into the territory. Such an active demand could easily be misinterpreted by manufacturers as complete acceptance of the harvesters in their present state of development, particularly if the acute shortage of harvest laborers was not known and taken into account.

The 1951 harvest was one of the worst experienced in recent years. Heavy rains covered practically all districts just before or during the start of harvest. Additional moisture in the form of rains and snows kept the fields muddy throughout October and November. Severely cold temperatures occurred early in November, ranging down to —17° F. in several districts. This froze the tops, crowns and upper portions of the beet roots severely and delayed harvesting. Normally our harvest is about completed in the first week of November but this year approximately 625,000 tons remained in the ground after November 5. Harvest of this tonnage was not completed till after December 10, or fully 30 days past normal.

Much of the harvesting in November and December was done under very adverse field conditions. This was indicated by the fact that for several week the average percent dirt tare was above 20 percent, or approximately 3 times the normal. Farm labor was scarce, high priced and undependable. Many growers were unable to hire "picking table" workers at any price during periods of unfavorable weather.

In spite of all these unfavorable conditions—77 percent of the crop was harvested mechanically. One thing this harvest did was to accentuate both the strong points and the weaknesses of the several makes of harvesters used. Thinking that a "grass roots" appraisal of the various machines might be of value in furthering improvements in the future, we asked our 71 fieldmen to submit their frank opinions of all machines used—based on their contacts with growers.

Each fieldman furnished a questionnaire on the different makes of harvesters operating in his district. The questions were designed to cover the following points:

A. Effectiveness of the Machine in Harvesting Beets.
   1. Quality of topping.
   2. Number of beets missed.
   3. Dirt elimination.
   4. Capacity.
   5. Mech. dependability under various conditions.
B. Effectiveness in Harvesting Tops.
   1. Top disposal.
   2. Condition of tops.
C. Improvements needed.
D. Growers' opinions re machine.

An attempt was made to summarize these various reports covering the principal beet harvesting machines in use in our district. (See table on pages 626 and 627).

From the table it can be safely stated that all of the present harvesters in use have serious drawbacks both to the farmers and to the factories. It is to be hoped that a recognition of these and a realization of their magnitude will stimulate efforts on the part of manufacturers to improve these machines in the immediate future. For our area these improvements should cover the following points:

1. Better topping of beets to include mechanically thinned beets. The beaters used in conjunction with the standard topping devices on International machines look promising.

2. Better harvest of beet tops. With the exception of the old No. 54 John Deere harvester, the loss in feed value of the tops is very high. This loss probably averages 75 percent of the potential value. The realization of this loss is one reason many growers have been reluctant to use harvesters instead of hand laborers. Some still refuse to use harvester machines.

It is conservatively estimated that the feed replacement value of well handled field cured tops (average of 27 separate tests) is 46 lb. corn and 150 lb. hay per ton of beets and at present prices this amounts to:

Corn	$1.56	(3.40 per cwt.)
Alfalfa	2.25	(30.00 per ton)
	$3.81	Total

This year the average selling price of mechanically harvested tops was approximately $1.00 per ton of beets, or a loss of $2.81 per ton. With an average yield of 15 tons per acre, this loss was more than $40.00 per acre ($42.15). On the other hand, fields where hand labor was used brought a premium price (up to $2.75 per ton of beets).

Manufacturers should recognize this loss for, without doubt, the popular harvester in the future will be the one which best handles the tops.

3. Better elimination of dirt and trash. This is important, both to growers and to factories.

a. From the growers' viewpoint.
The excessive dirt handled makes a serious increase in harvesting costs, both through the extra labor needed to separate beets from dirt and in the extra tonnage of dirt handled. That there is more tare on mechanically harvested beets is shown by a study of comparative tares from hand topping and machine harvested beets at one station in each of 14 factory districts. This showed an average of 15.40 percent for machines and 12.34 percent for hand topping, an average increase of 3.06 percent, or approximately a 25 percent increase in tare over hand topping.

b. From the factory viewpoint.

The excessive amounts of dirt and trash delivered with mechanically harvested beets create several serious problems, among which are:

1. Storage pile losses are increased materially.
2. Factory slicing is reduced and costs increased.
3. Disposal of excessive quantities of mud and rocks is a serious problem and an added expense.

While the problems of machine harvesting seem large at present, I am hopeful that by continued suggestions for improvements, and experimentation on the part of everyone connected with the beet industry, the major weaknesses can be quickly improved.

Two Screens for Receiving Stations and Their Trash Removing Properties

E. M. DANIELS[1]

With the advent of the mechanical sugar beet harvester in the mid-'40's and the probability that sugar beets would be harvested entirely by machinery in the future, it became apparent that existing dirt and trash removing devices at receiving stations and factories had become obsolete. Although these screens and trash drags had been successful for many years, they could only attempt to extract the foreign material hauled in with the beets from mechanical harvesters. The ultimate result was damage to the factory's slicers and in extreme cases reduced factory slicing capacity.

Even though some improvement in screening ability has been made in the mechanical sugar beet harvester since its inception, and possibly further advancements will be made in the future, there apparently is a definite limit to the amount of screening capacity which a harvester can attain. The machine must be made portable and compact enough to be maneuverable, which precludes the possibility of incorporating into its design large and elaborate filtering devices. From a practical standpoint, therefore, damaging extraneous matter must be eliminated by other methods.

New Receiving Station Screening Equipment for Processors

Assuming that the processor must bear the burden of extracting the heavy dirt and trash delivered by mechanical harvesters, especially by those with high harvesting capacities which employ no hand sorting labor during their operation, the logical place to make the extraction appears to be at the receiving station itself, rather than within the factory's cleaning system. Two major developments in receiving station screening equipment have been made and have shown outstanding results.

Ogden Iron Works Co., Ogden, Utah, Combination Screen

This outstanding screening apparatus has been incorporated into the company's Silver, model 1950, 36 inch dump, and it has demonstrated its effectiveness by removing large quantities of loose beet tops, weeds and other foreign substances from mechanically harvested beets.

The Silver screening system is divided into two parts involving two dissimilar mechanical actions in the separation and removal of dirt and trash from the beets. The beets, dirt and trash are first introduced from the elevator belt to the kicker dirt screen. This screen corresponds to the Reincks type, and although the wheels, or kickers, are of different design, they have a similar action to the Reincks rolls. There are eight complete rolls of twenty-two individual kickers per roll. The first seven rolls consist of rubber kickers and the kickers in the final roll are of cast steel, or iron. All rolls are 5 feet 6 inches in length, the kickers are 13½ inches in diameter, and all kickers are spaced within ½ inch of each other. The composite rolls extend to a width of 6 feet 10 inches, yielding a total screening surface of 37.58 square feet.

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[1] Chief Agriculturist, Holly Sugar Corp., Hamilton City factory.

The entire screen lies level and all kickers are of the same elevation, the beets and trash being propelled from one end of the screen to the other by the revolving action of the kickers. All kickers rotate in one direction toward the discharge end of the screen. Rubber kickers have definite advantages over the steel type in that they are less susceptible to sticky mud adhering to them and are not so abusive to the beets. Also, less tail breakage and gouging of the roots is apparent and noteworthy. The rubber kickers are, however, more vulnerable to clogging with wet trash, particularly loose beet tops, probably due to their flexibility and consequent inability to tear through the trash.

The rubber effects more friction to the foreign material. Since the drive gear box of the following longitudinal rolls is immediately next to the final kicker roll, a bulkhead is formed for trash to hang and build up, and the use of steel kickers at this junction point results in self cleaning so plug-ups are infrequent. At the passing of the final kicker roll the beets assume a drop of approximately 16 inches to the second phase of the screening system, the parallel counter-rotating longitudinal leafer rolls.

Parallel Counter-Rotating Longitudinal Leafer Roll. This section of the screening system is a rather unique arrangement of twelve parallel counter-rotating longitudinal rolls. These rolls immediately follow, and are integral to, the kicker dirt screen. The rolls are alternate rubber covered and steel, rotating in pairs, one clockwise and the other counter-clockwise. The steel roll is fitted with a steel spiral ribbon from the top end to within 12 inches of the discharge end, which provides a downward scrolling action. The rubber-covered roll is smooth with the exception of a 6 inch reversed-action spiral ribbon at the discharge end of the roll.

Since each pair of rolls rotates against each other with a downward motion, any foreign object caught between the rolls is rapidly pulled down between them. The long spiral on the steel roll greatly assists this action, and the rubber on the alternate rolls offers sufficient friction to be effective. Rocks, also, pass safely between the steel- and rubber-covered rolls. Without the short reversed spiral ribbon on the discharge end of the rubber-covered rolls, this screen assembly will plug badly at that end between the bearing points of the rolls. The reversed action spiral forces the trash upward and in an opposite direction to the long spirals on the steel rolls and is effective in preventing plug-ups at the rollers' discharge ends.

A blank space of 3 inches is left between the ends of the long steel roll spirals and the beginning of the short reverse spiral on the rubber-covered rolls. This allows an escape to any small beets having been caught tail-down between the rolls above the blank and therefore prevents them from being clipped in two. Tail breakage is nominal from the longitudinal rolls, and whole beets of marketable size cannot pass through the ¾ inch spacing between the 4½ inch rolls.

All rolls are the same elevation laterally and the entire group is tilted 8° toward the discharge end. This angle provides ample pitch for the beets to move swiftly toward the discharge end. At the intake end of the longitudinal rolls, the kicker screen distributes the beets and trash in a well disbursed manner and the beets travel down the rolls at an even depth.

Figure 1. Ogden Iron Works Co. combination screen installed on Silver 1950 36-inch dump. Note reverse spiral ribbon on lower ends of alternate smooth longitudinal rolls.

exposing the trash mixed in the beets to the grasping action of the rolls.

The rolls are 6 feet long and extend to a width of 4 feet 10 inches, giving the screen 29.0 square feet of rotating screening surface. This area plus the kicker screen's surface of 37.58 square feet yields a total of 66.58 square feet for the total system. Extraneous matter consisting of loose beet tops, small rocks and clods, weeds such as morning glory, loose water grass, small pigweeds, and other succulent species are readily removed by the longitudinal leafer rolls. Large clumps of sodded grass roots, thick or long weed stems and roots, and clods or rocks ¾ inch diameter or larger will not pass through the rolls and cannot be separated from the beets.

In concluding the description of the Silver double-action screening system, it should be noted that some soils in a muddy and sticky condition will adhere to the longitudinal rolls at their upper ends, and after a short period of time the resultant build-up will cause the rolls to stop. This condition is relieved by spraying a small stream of water at the head end of each roll. A pipe with one small hole per roll is installed at right angles to the upper ends of the rolls at a height sufficient to clear the stream of beets as it passes from the kicker screen to the longitudinal rolls. A common hand valve controls the volume of water required.

The introduction of water to the muddy rolls tends to loosen the sticking soil and it is cast off by centrifugal force. Althought the addition of water to the rolls somewhat affects growers' screenings weights, the use of

water is the most convenient method to effectively remove the mud. Usually no more than two or three gallons are used per load, and the additional weight is actually insignificant under the circumstances. Also, it is very seldom that the use of water is necessary, even during times of wet harvesting conditions.

The data in the folowing tables reflect amounts of dirt and trash screenings removed by both the kicker dirt screen and the longitudinal leafer rolls from ten representative loads of mechanically harvested beets:

Table 1.—Distribution of Screenings Between Kicker Dirt Screen and Leafer Rolls.

Loads	Beet Ticket Nos.	Total Raw Weight (Lbs.)	Weight of Screenings Kicker Dirt Screen (Lbs.)	Weight of Screenings Long. Leafer Rolls (Lbs.)	Total Lbs.
1-10	174499-509	151,010	4,350	3,030	7,380

(a) Percent of total each screen removed.

Screen	Lbs. Screenings Removed	% of Total Removed
Kicker Dirt Screen	4,350	58.94%
Longitudinal Leafer Rolls	3,030	41.06%
Totals	7,380	100.00%

(b) Percent of total loads screened out as dirt and trash (screenings)

Screen	% of Loads Screened Out
Kicker Dirt Screen	2.881%
Longitudinal Leafer Rolls	2.006%
Total % of loads which were screenings	4.887%

Note: Above investigations were made at resumption of harvest following a substantial rain. Loads contained abnormal amounts of wet soil in a free state and also clinging to beets.

Items 1 and 1-a of Table 1 indicate a total 3,030 lbs. of extraneous material removed by the longitudinal leafer rolls. This figure is significant since had they not been incorporated into the system, and had the kicker dirt screen been the only filtering device, 3,030 lbs., or 41.06 percent of the foreign matter contained in the 10 loads of beets, would have entered the factory cleaning system.

Table 2 shows an analysis of the foreign matter extracted by the longitudinal rolls. Four samples were taken at random from the ten loads tested in Table 1.

Table 2.—Percentage Analysis of Foreign Matter from Longitudinal Leafer Rolls.

No. of Sample	Total %	% Tops and Weeds	% Dirt	% Beets and Tails
1-4	100%	59.03%	13.47%	27.50%

Detail of % Beets and Tails:

Beets and Tails less than 1" in diameter	21.05%
Beets and Tails over 1" in diameter	6.45%
Beets and Tails over 1½" in diameter	0.00%
Total	27.50%

Although 13.47 percent of the total extraction was dirt, 59.03 percent of this total was a combination of loose beet tops and weeds, which are

Figure 2. Silver Engineering Works, Inc. Molnau screen installed on Silver - Roberts 30 - inch dump.

detrimental to the factory's slicers and process in general if not properly eliminated. Beets and tails comprised 27.50 percent of the total, but no beets over 1½ inches in diameter passed through the screen and the majority which were lost were under 1 inch in size.

Silver Engineering Works Inc., Denver, Colorado, Molnau Screen

This is the second new-type filtering system to be discussed. The Molnau screen may be classed as a rotating parallel longitudinal roll type, its having no Reincks, shakers, or other agitating devices to assist in removing dirt and trash. This screen has been installed on several types and sizes of the above Corporation's receiving stations including a Silver-Roberts, Serial No. 33825, 30 inch dump.

The unit at this receiving station is comprised of eight "squirrel cage" type longitudinal rolls which lie parallel to each other and to the stream of beets. These rolls are 6 feet long, 6 inches in diameter, and have ¾ inch spacings between the bars on the individual rolls. A one-inch space exists between each roll to allow passage of foreign matter. The Molnau rolls do not lie flat laterally but are grouped to form a concave slide, or trough. The two center rolls are at the same elevation, while the three rolls to either side are progressively higher in succession. One 6 inch smooth roller, parallel to the others, is situated at the top of either side of the screen to prevent beets from climbing over the sides. The entire unit drops 11° toward the discharge end, which has been determined to be the most efficient operating angle for this receiving station. The actual screening surface of the unit is

24 square feet, the rolls being 6 feet long and the concave surface width being 4 feet.

The Molnau rolls do not counter-rotate against each other, but are split into two banks. Looking toward the discharge end, all four rolls in the right-hand bank rotate in a clockwise direction, and the four in the left-hand bank rotate counter clockwise. This procedure tends to work the beets up the sides of the screen which in turn uniformly distributes the beets over the rolls, exposing the dirt and trash to their action. Knobs welded to each bar of the rolls form a spiral which enhances their grasping power.

Although the Molnau screen installed on the above receiving station is restricted in size, the filtering efficiency is apparently satisfactory. Results from tests have indicated that 74.22 percent of all foreign matter can be removed from mechanically harvested beets in certain areas with this particular installation. Since only 24.0 square feet of screening surface exist, it appears that the screen will successfully remove dirt and trash from mechanically harvested beets.

The Performance of the 1951 Models of the Molnau Screen

J. W. Axelson and G. E. Claassen[1]

This past season the American Crystal Sugar Company had a total of 17 Molnau screens in operation in the following districts: East Grand Forks, Minnesota, 2; Chaska, Minn., 9; Mason City, Iowa, 1; Missouria, Montana, 3; Oxnard, California, 1, and Clarksburg, California, 1. Careful observations were made in all areas and accurate comparisons of dirt removal were kept wherever possible. As a general statement, all areas have a high regard for the ability of the Molnau screen to remove trash.

In addition to removing more trash than other screens, tests also show that more dirt is removed by the Molnau, since trash alone would not account for the increased weight of material recovered from the screen.

The widespread distribution of these screens in areas with different soil types and harvesting conditions gave the Molnau screen a thorough testing. An early freeze in the Iowa-Minnesota area disrupted comparative tests which were being conducted there. However, Missoula, Oxnard and Clarksburg were able to obtain valuable information comparing the Molnau with other screens.

At East Grand Forks, Minnesota, the Molnau screen was found to be very efficient for removing trash under dry conditions; however, difficulty in clogging was experienced under wet soil conditions due to the sticky gumbo in the Red River valley. Mention was made also of the fact that the Molnau screen is difficult to clean when clogged, due to its tubular construction.

Missoula, Montana, reported no mechanical difficulties whatsoever, and the 1951 model did not clog as readily as the 1950 model.

Table 1.

Type of Dump	Type of Screen	Average of tare
1929 Lynch	1951 Molnau	7.0
1945 Silver Piler	Open Reinks	10.7
1941 Silver Piler	Closed Reinks and blower	8.9
1929 Lynch	1950 Molnau	7.9
1946 Silver Stationary	Open Reinks and blower	10.8
1929 Lynch	1950 Molnau	8.9
1946 Silver Stationary	Open Reinks and blower	11.6

The tabulation in Table 1 compares the 3 Molnau screens operated in Missoula in 1951 with other screens at the nearest stations. These figures are average for all beets delivered to the station concerned for this year:

As shown in Table 1, the Molnau is favored 3.7 percent in the first comparison, 1 percent and 2.9 percent in the second comparison and 2.7 percent in the third comparison.

[1] Agricultural Superintendent, Chaska, Minn., and Agricultural Superintendent, Mason City, Iowa, respectively for American Crystal Sugar Company.

The Chaska, Minnesota, area has had several Molnau screens in operation for the past three years. Those people report no mechanical difficulty during that time and the screen has done an excellent job of trash removal and cleaning. Less work stoppage was experienced with the Molnau screen than with any other screen used.

At Mason City, Iowa, the Molnau screen is highly recommended for its trash-removing abilities under extremely dirty conditions. Some difficulty was encountered with partial clogging on the tail end bearings. Correction of this difficulty will be discussed later. The overall performance of the Molnau screen in this area was excellent.

At Oxnard, California, a very complete test was conducted comparing a 6-ft. Molnau with a 6-roll Reinks having no reverse rolls.

Various pitches were used on the Molnau screen in an attempt to determine the proper setting for local conditions. Pitches of 2, 2⅜ and 2⅝ inches per foot were tried with a speed of 150 RPM on the screen.

When the Molnau screen was first installed, it was visibly noted that it was removing more loose trash and leaves than the Reinks; however, from the results of actual tests shown in Table 2, the difference in tare weight indicated that it was actually removing more dirt, for the weight of leaves and trash alone would hardly account for the increase in recovery shown by the Molnau screen.

Table 2.

Random Loads from All Growers

Type of Screen	Number of Loads	Number of Tons	Percent of Dirt	Percent of Top Tare	Net Recovery
	Sept. 3 to 8 incl.		Pitch 2⅜" per foot		
Reinks	391	3120	2.987	3.99	93.14
Molnau	330	2499	4.156	3.87	92.14
	Sept. 10 to 15 incl.		Pitch 2⅝" per foot		
Reinks	382	3029	2.481	3.98	93.64
Molnau	337	2584	3.383	4.13	92.63
	Sept. 24 to 29 incl.		Pitch 2" per foot		
Reinks	396	3106	2.288	4.50	93.31
Molnau	355	2563	3.205	3.94	92.98

The Following Two Tests Conducted on Individual Growers

Type of Screen	Number of Loads	Number of Tons	Percent of Dirt	Percent of Top Tare	Net Recovery
	Grower No. 1		Pitch 2⅜" per foot		
Reinks	43	358	1.436	4.85	93.78
Molnau	43	355	2.481	4.27	93.35
	Grower No. 2		Pitch 2⅜" per foot		
Reinks	42	280	1.57	4.44	94.06
Molnau	42	282	2.714	3.23	94.14

The figures in Table 2 are self-explanatory. Except at a pitch of 2⅝ inches, the Molnau screen shows a lower top tare in all cases. The net recovery is in favor of the Molnau screen with the exception of the individual test No. 2 which was practically even.

The only mechanical difficulty involved was in the drive clutch, which appeared to be too light. A heavier slip clutch is recommended. Under extremely cloddy conditions, clods are inclined to pass over this screen very much the same as with the Reinks.

At Clarksburg, California, more than 216,000 tons were run over a 12-roll Molnau screen with no major breakdowns. An attempt was made to compare results with previous years but due to different harvesting conditions the results were erratic. However, the screen performed very satisfactorily, removing a great deal of excess tops and trash, and, from the operating end, was a great factor in increased slice.

The Molnau screen was used in rather a unique arrangement at Clarksburg. In past years a 13-roll Reinks 7 feet wide with 4 reverse rolls was used, but it was not doing a suitable job with the increased use of mechanical harvesters. In 1951 a 10-foot 12-roll Molnau screen was installed in front of the Reinks for two reasons:

First, for the removal of as much trash as possible by the Molnau screen; Second, spreading the beets so as to have full advantage of the width of the Reinks screen for improved cleaning. The combination proved to be very acceptable, as 75 percent of the trash and dirt was eliminated before the beets reached the Reinks screen where, due to the spreading action, further dirt elimination was possible.

Summarizing briefly the reports from all areas we can conclude that the most remarkable qualification of the Molnau screen is its ability to remove trash and loose leaves. Comparative tests indicate that the Molnau screen is also efficient in dirt recovery. The pitch of the screen and RPM of the rolls are two big factors contributing to maximum performance. Dirt accumulating in the rolls does not hinder the performance of the screen, except under extremely sticky soil conditions which cause a buildup greater than the circumference of the roll itself. The Molnau screen will clog under these conditions and cleaning is difficult. Under excessive cloddy conditions there is a tendency for the clods to pass over the screen much the same as a beet.

With the increased amount of mechanical harvesting each year, it appears that the Molnau screen has its place in beet receiving equipment, through maximum utilization, to maintain and perhaps increase average daily slices enjoyed previously in processing hand-topped beets.

To help eliminate the grass and leaves, pegs were welded on the rolls. These pegs snag and carry the trash through the screen. Originally about 10 ½ inch x ½ inch x ½ inch pegs were used per roll and no set pattern followed. As the importance of these pegs became apparent, further study and experiments were conducted.

The best results were achieved by using 26—⅜ inch x ⅜ inch x ¾ inch pegs placed in a scroll pattern around each roll. All 1951 screens were constructed with this type of roll.

At no time has there been any appreciable loss of tailings between the bed rolls of the screen, the tendency being for these to be carried to the outside rolls. Because of this it was decided to allow more space between these rolls (from 1 inch to 1 1/16 inch). This spacing will be increased to 1⅜ inch in the 1952 model, with the exception of the center spacing.

To date all screens have had the same spacing between the bed rolls. Due to the extremely wet and muddy condition this past year, there were

times when these rolls would build up until there was no clearance between the rolls, this being especially true at the center rolls due to the bulk of the beets coming off the belt at this point. To overcome this in the future, wider spacing will be made between the 2 center rolls (an increase from 1 1/16 inch to 1½ inch), the thought being that the accumulation can at no time be greater than the spacing between this roll and the one next to it which rotates in the same direction, thus assuring spacing between these two rolls at all times.

To ease the difficulty we were having with the tailings and trash at the edge of the screen, the outer elevated roll was raised and brought in so that the inner facing of this roll was directly in line with the center of the last bed roll, providing more clearance between the roll and the housing. The spacing was increased from 1 inch to 1⅜ inches.

The scroll on this elevated roll was also changed from one which fed the untopped beets and trash directly to the discharge end to a two-way scroll. The scroll on the lower ¾ of this roll was reversed. This tended to bring the untopped beets and trash back up the screen, eliminating much of the congestion experienced with the earlier models and at the same time giving the screen further opportunity to remove tops, etc. The scroll on the upper end of this roll fed downward and where it joins the reversed scroll they were overlapped, developing more aggressive cutting action. The result of these changes were very satisfactory. Additional increase in the spacing from 1⅜ inches to 1⅝ inches will be made on the 1952 screens and the elevated roll will overlap about ¾ of the last bed roll.

It is obvious from the data brought out earlier that the Molnau screen performance is in most instances superior to that of all other screens in our districts and if the design of the screen as originally fabricated by Mr. Molnau had been followed, the screens which were manufactured by Silver Engineering Works would have performed equally as well. One of these Silver Engineering fabricated Molnau screens was installed at Mankato, Minn., and after two years of use and various changes having been made to it, endeavoring to covercome its weaknesses, it has now been decided that it must be dismantled and rebuilt to conform with the screen design as originally developed by its inventor.

Piling of Beets from Railroad Cars

AUSTIN A. ARMER[1]

One of the consequences of mechanical harvest in California has been a marked upswing in the daily harvesting capacity of growers coupled with a strong desire to complete their harvest before the rainy season begins. But daily factory capacity is fixed, and beet deliveries in excess of slicing capacity can be accepted only if storage facilities can be provided. Such storage facilities are customarily arranged as soon as seasonal temperatures fall to a point where piling is a reasonably safe risk.

However, piling with existing equipment has always been limited to beets delivered by truck to the piling machines. Under these conditions, it was impossible to divert beets from railroad cars to pilers unless by rehandling with trucks. (Such a system has never been practical because of the cost of rehandling together with the attendant damage to beets.)

When the factory at Spreckels, California, was faced with an unprecedented influx of beets from the 1950 harvest, the need for all possible piling facilities became acutely evident. George P. Wright, district manager at the Spreckels factory, urged the immediate construction of facilities for piling beets received by railroad, and his encouragement and suggestions made the accomplishment of this procedure a reality.

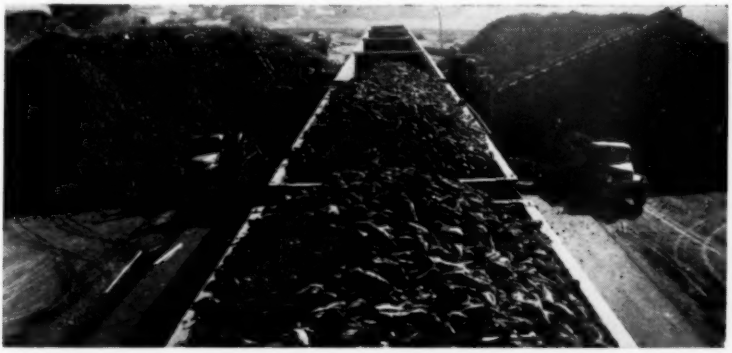

Figure 1. Two 36-inch pilers were located on either side of a trestle carrying the cars to be unloaded.

The elements of rail piling system as finally worked out were:

1. A piling area approximately 100 ft. wide and 1,200 ft. long.
2. A track extended along the center of this area on a trestle 7 ft. high.
3. Conventional pilers to receive beets discharged from bottom dumping gondola cars spotted on the trestle.
4. Receiving aprons mounted on the piler hoppers to transfer the beets from the cars to the pilers.

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[1] Agricultural Engineer, Spreckels Sugar Company.

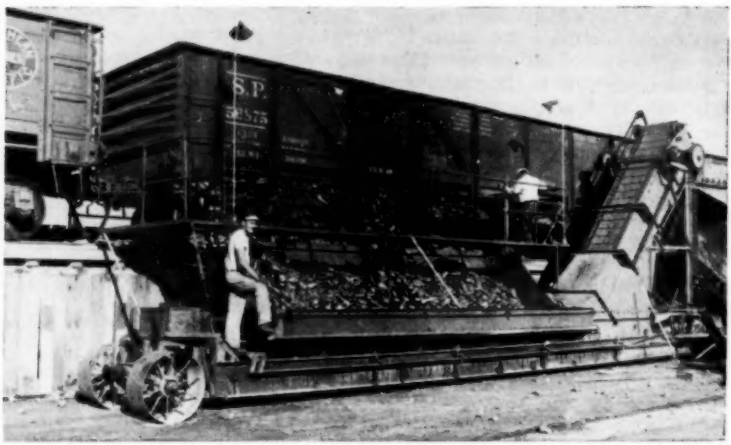

Figure 2. Each piler was provided with a special receiving hopper long enough to accommodate beets discharged from half a car length.

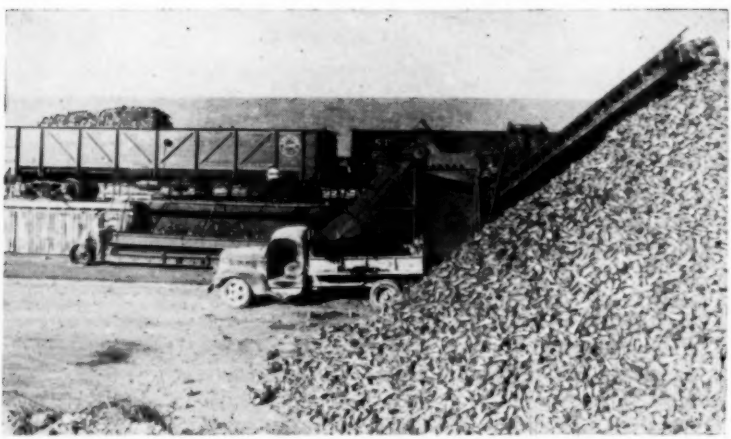

Figure 3. The capacity of the special hopper on each piler was adequate to receive beets as rapidly as discharged from the car.

The system, as above outlined, was accomplished by making use of one of the old "wet bins." The flumes of these bins were filled in, and the adjacent ground surface leveled and covered with plant-mix road surfacing ("black top"). The sloping sides of the trestle which supported the original track were replaced with vertical sides in order to permit two pilers to operate as close to the center of track as possible.

Aprons were designed to attach to the piler hoppers, and these were arranged to accommodate the contents of one-half carload of beets. In operation, the bottom doors of the car to be unloaded were opened for one-half the length of the car and the beets discharged. The car was then pulled one-half of its length so that the second half was spotted over the aprons. The remaining bottom doors were then opened and emptying of the car completed.

Performance of the Installation

After the unloading crews and piler operators had become accustomed to this new procedure, it became possible to unload cars at the rate of three per hour. This is substantially the same unloading rate as could be realized when unloading similar cars, either into a "wet bin" or into a conventional car dumping hopper.

There was a tendency of beets to spill or bounce off the apron, but this was corrected by installing wings on the apron, and by paying close attention to the details of unloading.

Condition of Beets in the Piles

Rail beets piled with the equipment as described were subjected to one more cleaning operation than they would be had they been dumped direct from grower's trucks. This was very fortunate because, as the season progressed, the amount of dirt delivered with the beets mounted higher and higher and the additional cleaning afforded by the rail piling procedure was a tremendous benefit. The figures were not available to show the percentage of additional dirt removed, although sample weighings indicated that the dirt removal through the second handling was substantially less than that through the first handling.

The overall performance of the system may be summarized as follows:

1. Piling of 40,000 tons of rail beets became possible.
2. Unloading time per car was substantially the same as when similar cars were dumped into conventional hoppers or "wet bins."
3. The double cleaning of beets entering piles resulted in lower piling losses for rail beets than for truck beets subjected at the same transit time.

Large Scale Supplemental Ventilation of Sugar Beets Stored for 106 Days[1]

ROBERT S. GADDIE AND BION TOLMAN[2]

Supplemental ventilation was applied to 22,500 tons of beets stored for an average of 106 days during 1950-51. Beet piles were 22 feet high and 130 feet wide and sections of two piles were ventilated. Air ducts were made from used 55-gallon oil drums with the ends cut out and ducts were spaced 20 feet apart. The average amount of air supplied was 12.5 cubic feet per minute per ton of beets.

Analytical data on the effect of the ventilation was obtained from captive samples in wire baskets which were distributed throughout the two piles in a regular pattern. In each pile the 70 feet adjacent to the ventilated section was made the control or check section. At 10-foot intervals, as the pile was built, 6 captive samples were placed in a vertical plane as shown in Figure 1.

Thus there were 72 captive samples representing 140 feet (approximately 6,000 tons of beets) in the unventilated control sections. In the first 100 feet of each of the ventilated sections, 6 captive samples were similarly placed in a vertical plane every 10 feet. These were so placed that vertical planes representing 6 samples came alternately over a ventilating duct and between ducts. For the next 120 feet of ventilated pile 4 similar sets of samples were placed in planes at 30-foot intervals placing sets alternately over and between ducts with one duct separating sets. Thus a total of 156 captive samples was distributed throughout the ventilated sections of the two piles.

The beet samples were obtained as follows: From a single truckload of beets, 3 samples were selected so that each of the three consisted of the same number of beets of similar size, shape and weight. The beets were all brushed clean and one of the three samples was weighed and analyzed immediately for sugar. The second sample was weighed, placed in a wire basket and the basket placed in the proper place in the ventilated control section of the pile. The third sample was placed in a rubber bag and held until the piler had reached the section of the ventilated pile corresponding to the same place in the control section in which its mate, sample number 2, had been placed. At this time sample number 3 was removed from the rubber bag, weighed, placed in a wire basket and the basket placed in the pile according to plan. No sample was held more than 48 hours in the rubber bags.

To obtain an adequate record of temperatures in the interior of the pile, 3 tubes of different lengths were driven into the pile in each vertical plane formed by a set of 6 samples (see Figure 2), and thermometers lowered to the bottom of these tubes. Thirty-six thermometers were in the control sections and 78 in the ventilated sections.

During most of the storage period fans were operated whenever the temperature of the ambient air was lower than that of the beets. Figure 3 is a composite graph showing for each day of storage the maximum and minimum temperatures of the ambient air, maximum, minimum and aver-

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[1] Toppenish, Washington, 1950 Crop.

[2] General Chemist and General Agricultural Superintendent, respectively, Utah-Idaho Sugar Company.

FIGURE 1

Location of Captive Samples and Ventilating Ducts

FIGURE 2

Location of Thermometers

FIGURE 3

age temperatures of the unventilated and ventilated piles and the hours the ventilating fans operated.

To obtain some information on the probability of freezing beets in the interior of a pile by ventilating with low temperature air, continuous blowing was maintained for a 4-day period when the ambient air temperature was 23° F. maximum and 0° F. minimum (see Figure 3). All beets in the pile exposed to the prevailing winds were frozen for a distance of about 7 feet above the duct. Beets in the pile shielded from the prevailing winds were not frozen.

In evaluating the data from the captive samples, the 72 samples in the unventilated control section may be compared with either the 156 samples in the entire ventilated section or with only those 72 samples in the ventilated section which are corresponding duplicates of those in the unventilated. Both calculations were made and the pounds of sugar lost per ton of beets per day differed by only .01 pound. However, it is believed that the most scientific basis for evaluation is to compare those samples which are duplicates. This camparison is shown in Table 1.

Table 1.

	Unventilated	Ventilated
Average days storage	99.000	105.833
Average weight, pounds, going into storage	24.167	23.915
Average weight, pounds, out of storage	22.692	22.719
Average weight loss, %	6.103	5.001
Average % sugar going into storage	15.119	15.119
Average % sugar out of storage	13.850	14.187
Average pounds of sugar lost	.511	.393
Average pounds sugar lost per ton beets per day	.427	.311
Difference—pounds sugar saved per ton beets per day	.116	

On the 22,500 tons of beets ventilated this savings amounts to 2,762 bags of sugar, which is all recoverable at practically no operating cost.

The cost of supplemental ventilation of beets at Toppenish is shown in Table 2.

The savings due to ventilation at Toppenish during 1950 are perhaps less than might possibly be obtained on a similar storage period under average conditions in the Yakima valley. Storage conditions during the 1950-51 season approached the ideal and while the beets were placed in the pile in fairly muddy condition due to considerable rain during harvest, the generally cold storage temperatures resulted in the unventilated piles keeping in better than average condition.

West Jordan, Utah, 1950 Crop

The experiment at West Jordan is reported to show the marked effect ventilation has on processing quality of certain beets. Many years of past history have demonstrated that Taylorsville beets under the best of storage conditions spoil very rapidly in the pile, so 5,000 tons of these beets were ventilated. The ventilation was carried out in a manner similar to that used at Toppenish and with duplicate captive samples to obtain the analytical data. The average storage time of the unventilated check sections was 57 days; of the ventilated sections 62 days. The sugar saved per ton day of storage by the supplemental ventilation was 0.201 pounds.

The most striking results from ventilating Taylorsville beets were obtained in factory operations. The usual poor storage character of these beets

Table 2.

Capital Costs	Labor	Material
17 Ventilating fans	$	$4,415.48
Switches, coils, heaters, etc.	443.89	261.18
Bearings for 9 fans	83.43	103.82
Electric cable	604.35	1,296.10
1,160 drums		2,604.29
Preparing drums	919.90	802.41
Miscellaneous		53.77
	$2,087.57	$9,537.05
Total	$11,624.62	
Capital Cost per Ton Beets	$ .52	

Operating Costs		
Hauling and placing drums	$ 641.15	$ 92.42
Reclaiming drums	464.16	134.61
Placing and removing fans	302.26	25.28
Power		2,777.22
Drum replacements, 10%		260.43
Depreciation, maintenance and repair, 10%		1,162.46
Miscellaneous		152.42
	$1,407.67	$4,604.84
Total	$6,012.51	
Operating cost per ton beets	$ .27	
Operating cost per ton beets per day storage	$ .00252	

was evident again this year in the unventilated sections of the pile, and was marked not only by spoilage areas but by the difficulty with which these beets were processed. Juice colors were very dark, purities low and lime salts high. White pans required 3 to 4 hours to boil compared to a normal time of one and three quarter hours. Losses were high and sugar quality suffered. These conditions were completely reversed when the ventilated beets were processd (the last beets to be sliced). Juice and massecuite colors were excellent, purities increased and lime salts decreased. Table 3 illustrates this by showing a comparison of some of the factory operating data.

Table 3.

	% Sugar Beets	Purity Diffusion Juice	Purity Thin Juice	Lime Salts Thin Juice
Unventilated	15.64	82.3	88.8	.192
Ventilated	16.63	84.3	89.8	.111

It was possible, because of the excellent condition of these beets processed the last five days of campaign, to sweeten off the factory 36 hours after the last beet was sliced. This is compared to the usual time of 72 hours.

The marked contrast in the ease with which the beets were processed from these two storage piles seems perhaps extreme. However, we have noted in most of our factory districts that beets from some areas store better than those from adjacent areas. We believe that supplemental ventilation of those beets which are known to have poor keeping qualities is particularly efficacious.

Beet Shed Ventilation in California

LOUIS P. ORLEANS AND ROBERT H. COTTON[1]

Short-time ventilation of beets in storage bins is relatively new (1, 2)[2]. Usual practice in California is to coordinate harvest and factory operation so closely that beets remain in the sheds or bins only 10 to 48 hours. Air temperatures are often so high, however, that losses of commercial significance can occur even in these short periods of storage. The present paper is concerned with permanent ventilation installations at Tracy and Carlton, California.

Description of Equipment

The beet receiving sheds at the Carlton and Tracy plants in California are both of the same size and construction, and the ventilation installations are basically the same, with a few minor improvements being used at Tracy. The installation at Carlton ventilates half of the sheds, or about 2,000 tons of beets, while the one at Tracy, which is twice as big, ventilates the complete shed, or approximately 4,000 tons. At Carlton two 30-inch diameter main ducts are used with a 7.5-h.p. axial flow fan on both ends of each duct (1). The two ducts are in line and each runs half the length of the bin. There are seven lateral ducts on both sides of each main duct which carry the air to screened openings in the floor of the bin. These lateral ducts are spaced on 16-foot centers and each one is equipped with a damper for control of the air. The main ducts at Carlton are equipped with a spray chamber next to each fan. By saturating the air with moisture in a spray chamber the dry bulb temperature was lowered to the wet bulb temperature, a decrease of as much as 35° F. Since the temperatures encountered at Tracy are considerably lower than Carlton, the spray chambers were omitted in that installation.

In operation, the fans are turned on as soon as any beets are placed in the bins, and are left on until all the beets have been removed. The dampers are all closed when the flumes are empty, and they are opened individually as the beets cover the screened openings. When the beets are flumed out of the bins, the dampers are again closed as each opening is uncovered. Thus, maximum use of the available air supply is obtained. Under full load, when the bins are completely filled, the air supply is 27 cfm per ton of beets, and increases as the amount of beets in the bin decreases.

At Carlton, a man has to crawl underneath the bin to operate the sliding dampers. This procedure is rather bothersome, especially when the labor supply is short, so at Tracy pivoted dampers are used, and they are lever-operated from within the bin by the flumers. At Carlton a flat screen was used to cover the duct openings in the bin floor. These screens allowed a considerable amount of dirt to fall through them and into the duct so that the duct needs to be cleaned frequently. The openings at Tracy were covered with a bar grid, or louvre, which prevented the dirt from entering the duct.

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[1] Research Engineer and Director of Research, respectively, Holly Sugar Corporation.
[2] Figures in parentheses refer to literature cited.

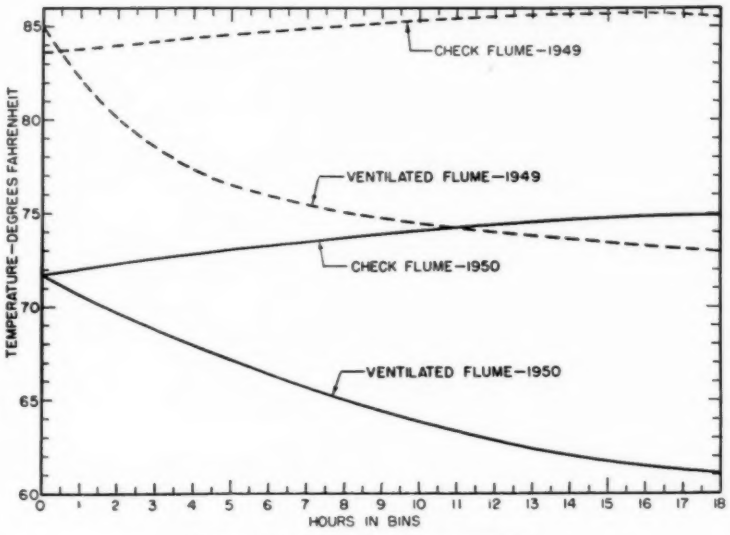

Figure 1. Average beet temperatures.

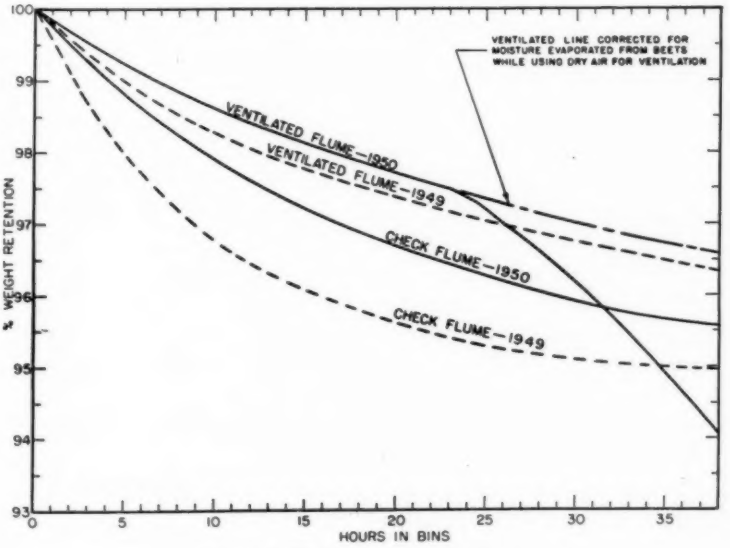

Figure 2. Weight retention curves.

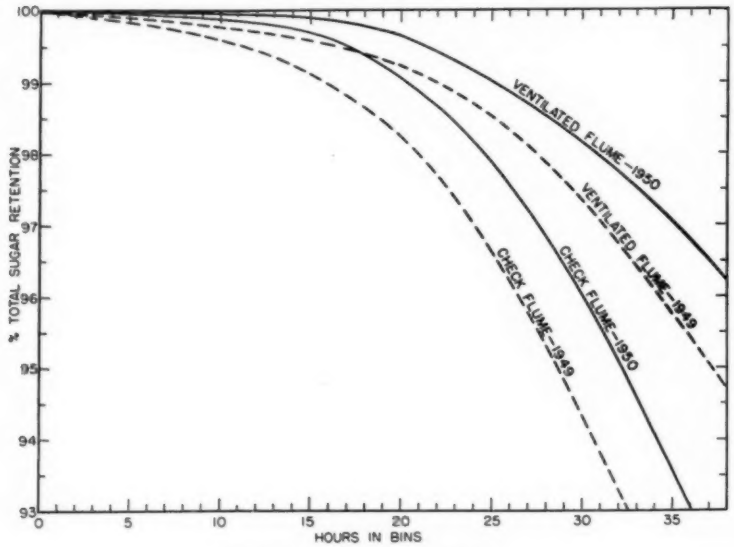

Figure 3. Total sugar curves.

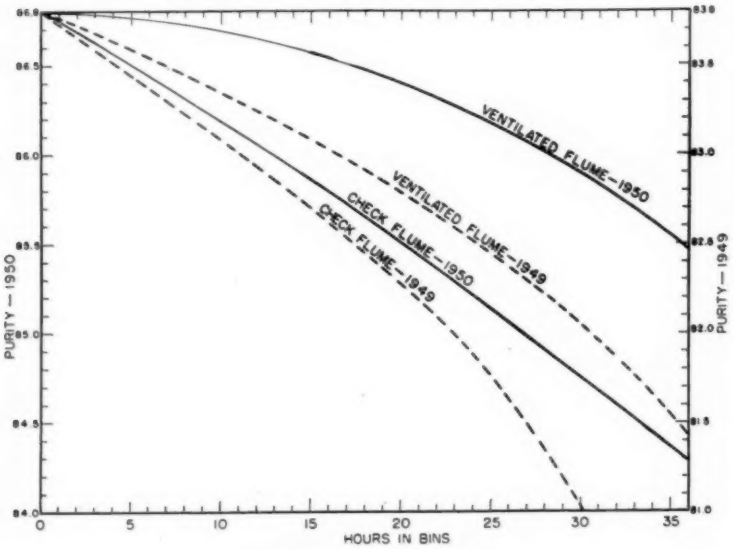

Figure 4 . Purity curves.

Results

A small scale experiment was conducted at Carlton in 1949, and the results of this experiment have been published (2). The commercial size equipment was installed at Carlton for the 1950 campaign, and three tests were conducted that year to evaluate it.

In each test 20 matched triplicate samples, as described elsewhere (2) were used to determine losses in the beets while being held for processing. It was not possible to remove ventilated and non-ventilated beets simultaneously and, therefore, statistical analysis was not practical. The magnitude and consistency of the data, however, gave us confidence in the over-all results. Curves were plotted for temperatures, weight retentions, total sugar retention and purities. These curves, as well as the curves for the 1949 tests, are shown in Figures 1, 2, 3, and 4. It can be noted that although temperature reductions were of the same magnitude for both years, differences in weight and total sugar retention were smaller in 1950 than in 1949. This is to be expected, as temperatures were lower when the tests were conducted during the second week of June, 1950, than during the first half of July, 1949.

The results for 1950 closely parallel those of 1949, with the savings for 1950 being approximately 60 percent of those obtained in the 1949 tests. The results obtained in 1950 should be closer to an average for the entire campaign with less savings obtained in May and greater savings during the hotter month of July.

The average retention time for beets in the bins at Carlton is 15 to 20 hours. Figure 1 shows that the temperature at the end of 15 hours was 75° F. for the check flume, while the ventilated flume was 13.5 degrees cooler, or 61.5° F. Figure 2 shows that beets in the ventilated flume lost 1.8 percent of their original weight in 15 hours, while the check flume lost 2.7 percent. The total sugar loss at the end of 15 hours was 0.1 percent for the ventilated flume and 0.25 percent for the check flume, or 2.5 times as great as the loss in ventilated beets (See Figure 3). Figure 4 shows .7 percent greater drop in purity for the check flume in 15 hours than for the ventilated one.

With an 80-day campaign at Carlton and 2,000 tons of 18 percent sugar content beets being ventilated for 15 hours every other day, the saving in actual sugar would be 43,200 pounds per campaign. Combine this actual saving in sugar with the higher extraction possible with higher purity from ventilated beets, and the ventilation installation will easily pay for itself in two years of operation.

The equipment for ventilation at Tracy was installed for the 1951 campaign, but no tests have been conducted there as yet.

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1951. "Beet Sugar Technology," P. 117, New York, Reinhold Publishing Corporation.

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1950. "Commercial Ventilation of Beets in Storage," Proc. Amer. Soc. Sugar Beet Technol., Sixth Gen. Meet., p. 637.

Ventilation of Storage Beets by Forced Air

A. G. QUAMME[1]

In many areas where sugar beets are grown, it is necessary to store a considerable portion of the crop. In these areas, the harvest season is often short and deliveries must frequently be completed in a five- or six-week period. Therefore, in some areas of the American Crystal Sugar Company's operations, as much as 50 percent of the total tonnage must be stored. In such instances every precaution must be taken to prevent heating, because when started this will spread rapidly, and in a short time thousands of tons can be damaged or ruined entirely.

The various conditions which cause excessive heat in the storage piles are: high temperatures during the harvest period which will cause beets to become wilted in the fields or while enroute to the factory, beets which contain an excessive amount of dirt, leaves, trash and frozen beets. All of these factors can cause excessive heat in the piles and subsequent spoilage. With the advent of the mechanical harvesters, a greater amount of leaves and trash is delivered with the beets and this has increased the danger of spoilage.

In 1947, temperatures prevailing in southern Minnesota and northern Iowa during the harvest period were exceedingly high, the beets became badly wilted during the harvest operation, and therefore went into the storage piles in a wilted condition. This shut off circulation of air through the piles and as daytime temperatures continued to be high, conditions were conducive to spoilage which spread rapidly and caused the loss of several thousand tons of beets in many beet growing areas.

Experimental Work

Prior to 1947, experiments had been carried on for several years to determine whether heating of storage beets could be lessened or eliminated by forcing cool night air through the piles and these experiments had shown a great deal of promise. The great losses incurred in 1947 accelerated this work and in 1948 the American Crystal Sugar Company started an extensive program of ventilation by this method. This program was expanded still further in 1949 at which time 140,019 tons were ventilated. This has now been adopted as a regular practice by this company, 193,000 tons being ventilated in 1950 and 214,420 in 1951.

General Procedure

The general procedure as used by this company is about the same as in all areas. Ducts are made up of used steel drums with the ends cut out, placed end to end with a 2-inch space between drums. In some instances the ducts are made up from 18 inch corrugated culvert pipe in which holes are punched on the sides and top, such holes being about 2 feet apart. These ducts are placed either crosswise or lengthwise of the pile with one end of the duct extending to the outside of the pile so fans can be inserted. When ducts are placed crosswise they are spaced from 16 to 30 feet apart, depending on the amount of ventilation desired.

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[1] Manager, American Crystal Sugar Company, Mason City, Iowa.
[2] Numbers in parentheses refer to literature cited.

Navy-type fans with two-speed motors and magnetic controllers are used, each fan having a capacity of 10,000 to 12,000 CFM. These fans are moved from duct to duct as needed. The fans are operated only when the air temperature is lower than the temperature within the piles. In some systems the fans are started and stopped by thermo-control and in other systems this is done manually.

Thermometers are placed at various points and different levels in the piles to determine where ventilation is needed. If any spot shows indication of heating several thermometers are inserted and, if the temperature cannot be brought down by ventilation, this section is removed and sliced immediately.

Results Obtained

Much data has been accumulated during the several years that this system has been in operation, much of which was recorded in the 1948 and 1950 Proceedings of the Society.

Table 1.—Comparison of Sugar Losses in Ventilation and Non-Ventilation Piles—From Data Collected in 1946, 1947, 1948 and 1949 By American Crystal Sugar Company.

		Loss in lbs. of sugar per ton per day			
Year	Location	Ventilated	Days in Storage	Non-Ventilated	Days in Storage
1946	Clarksburg (1)	.94	35.0	1.55	15.0
1947	Rocky Ford (2)	.122	40.0	1.505	40.0
1948	Clarksburg (3)	.75	50.1	1.12	25.3
1949	Clarksburg (3)	1.15	27.0	1.55	32.1
1948	Mason City	.575	26.8	1.06	17.0

In every instance this data shows that sugar losses are greater in the non-ventilated piles than in ventilated piles. Observations have also shown that there is much less heating in the ventilated piles than in non-ventilated piles; therefore there is less spoilage

Conclusions

Through several years of extensive experimental work as well as large scale operations, the following conclusions have been arrived at (1), (2), (3):[2]

Sugar losses are reduced by ventilation.

Spoilage of storage beets can be greatly reduced, if not entirely eliminated by ventilation if done at the right time.

The best results are obtained if the temperature of the pile can be brought down to 60 degrees or less as soon as possible after piling. This is especially true if daytime temperatures at the time of piling are high.

When daytime temperatures are 60 degrees or lower at the time of piling there is very little need for ventilation.

From records kept in one district in 1950, the operating costs of labor and material on 31,520 tons ventilated was .0292 cents per ton. This did not include the original cost of fans, ducts, wiring and permanent equipment.

Ventilation by this method will not entirely eliminate heating and spoilage of storage beets but if the beets are reasonably free from leaves and trash and in fair physical condition, experience has proven that there is very little danger of spoilage.

From our experience, controlled ventilation of storage beets by forced air has proven to be economically sound and the best method developed to date to reduce the spoilage in storage beets.

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Radiant Ray Frost Protection as Applied to the Exposed Face of Sugar Beet Storage Piles

READ A. WILKINSON[1]

In areas where sugar beet storage piles are being constructed during the late fall, a problem of frosted unstorable beets presents itself. These beets because of nightly exposure to the mild freezing temperature are frozen sufficiently to form a spoilage plane which endangers all surrounding beets.

Attempts to combat this problem have to date consisted mainly of common frost control methods such as canvas coverings, smudge pots, wind machines, etc. These methods have not proven entirely successful; consequently, the further search for efficient control has centered upon the possibility of utilizing radiant energy.

The first encouraging attempts consisted in the use of an oil burning unit developed at Michigan State College. This was abandoned because of several objectionable features such as low efficiency, adaptability and safety.

The recent industrial application of radiant heat from infrared bulbs has to date been confined to high energy levels for drying and heating in the metals, food, plastics, paper and textile industries. Its use in low energy levels such as a frost guard unit for beet piles, to our knowledge, has never been tried. However, because of the successful industrial application of electrical infrared radiant energy and the fact that the infrared bulbs transmit "near" infrared energy not absorbed by air, a decision was made to apply it to the problem of frost protection.

In experimental work previously attempted with regard to the action of frost upon sugar beets it was determined that the critical temperature below which the cell structure would rupture due to freezing was approximately 27° F. Another determination arrived at from frost protection experiments carried on by the University of California was that it required at least a 10 to 13 B.T.U. per square foot application to prevent freezing of fruits or vegetables for ambient temperatures down to 24° F.

Considering the above limiting data, the circular face of pile and the adaptability of a light compact mobile unit, an electrical radiant ray frost guard was designed. The original unit consisted of a 140° circular bank of 48 375-watt lamps of special heat-resistant glass to withstand intermittent moisture conditions. The energy level of this unit was 4.73 watts or 16.18 B.T.U. per square foot per hour with a power demand of 18.0 K.W.

Preliminary trial applications were made in order to determine the lamp location for maximum coverage and efficiency. A radiometer was used to make such a determination. When the unit was located upon the ground 9 feet back from the beet pile base only about 40 to 50 percent of the face, located directly in front of the lamps, was sufficiently covered with the 13 B.T.U. per square foot or more necessary for adequate protection.

In order to remedy this condition two changes were made: First, the unit was suspended from the piler boom at the point of intersection between

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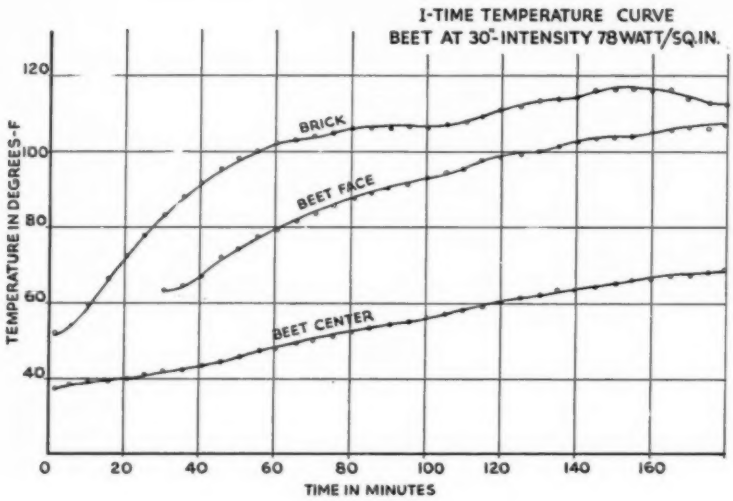

Figure 1.

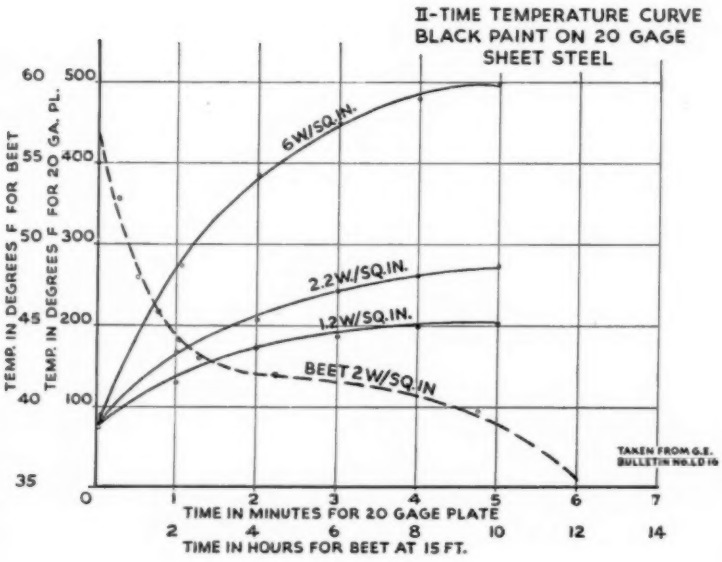

Figure 2.

the longitudinal center line of the beet pile and the chord extending from the two inside points of the pile arc. Second, the circular lamp bank was enlarged from 140° to 180°, thus increasing the energy level to 7.5 watts and 25.6 B.T.U. per square foot with a new power demand of 28.5 K.W.

From further preliminary trial data a typical performance curve was drawn which consisted of plotting time against temperature change. Similar curves are plotted in industrial applications for various materials, whose absorptivity is known and energy level calculated which are nearly uniform. However, in frost protection very few factors are constant and results can only be attained by maintaining an energy level high enough to prevent the temperature of beets from going below approximately 27° F. Consequently, similar characteristics between the curves for beets and that for other materials would not be expected because of these variations in outside temperatures, beet temperatures, moisture conditions, wind velocities, slopes of pile, distance of beets from source of energy and color of beets. Furthermore, for this reason the data from trials made is extremely difficult to correlate and group so that specific conclusions and recommendations can be drawn.

The performance curves in Figure 1 are for a beet placed 30 inches from the lamps. Two thermometers were placed in the beet, one in the center of the beet and the other 1 inch deep in the surface layer facing the lamps. To provide a basis for comparison a brick, whose rate of absorptivity is known, was subject to the same energy level of 7.8 watts per square inch and a curve drawn for it also.

Characteristic of all such curves is the tendency to flatten out, showing that for each energy level the result is a maximum temperature beyond which that particular material will not rise. This is the temperature at which the energy radiated by, convected or conducted from the work is equal to the energy received from the heat source. Such flattening out is prominent in the curve for the brick and started after 60 minutes. For the surface of the beet a slight tendency to flatten is indicated at 80 minutes and becomes pronounced at 150 minutes. The center of beet curve does not start to flatten until 146 minutes have elapsed with a definite tendency at 170 minutes. The difference between the temperatures attained by these two beet curves is due to the change in the volume effected by the radiation.

To aid in comparing these curves with those of known values a set of curves for black paint on 20-gauge sheet steel subjected to three different energy levels is included. The tendency to flatten, as will be noted from these curves, diminishes with the reduction in energy level and working temperature. The curves for the beets also have this common characteristic, except that it is inverted.

In applying this information to actual tests several deductions may be made: First, the slow rate of absorptivity of a beet indicates that the time of application is an extremely important factor. Second, the greatest protection is possible on the portion of beet directly exposed to the radiant rays. Third, since the bank of lamps is constructed in a circular shape in order to fit the contour of the beet pile face the energy level decreases with

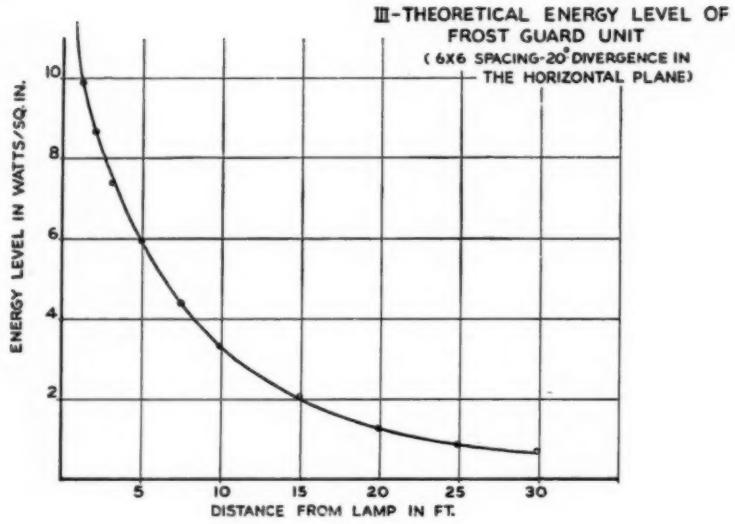

Figure 3.

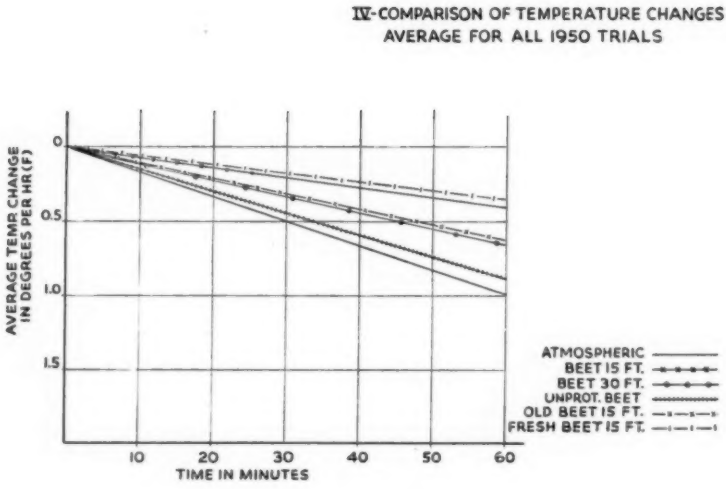

Figure 4.

distance from the unit. This is shown in Figure 3 where the theoretical values given are much higher than the actual average.

With all due consideration given the above information a series of trials was conducted as follows :

The bank of lamps was suspended from the Silver piler boom. Beets containing thermometers were placed on the face of the beet pile at 15 and 30 feet respectively from and within the range of the unit. As a check similar temperature data was obtained with respect to beets not subjected to the rays of the infrared bulbs. From the data obtained performance curves were plotted and conclusions formulated.

In Figure 4 the average temperature change of all trials is given in the form of straight line variations. A typical curve showing the actual temperature change is shown on Figure 2 and is inverted from the high energy curves also shown in this figure.

The following conclusions may be drawn from the accumulated data:

1. Protection from light frosts on the fresh face of sugar beet storage piles with this type of frost guard unit involving "near" infrared rays in low energy levels is possible and practical down to temperatures of 20° F.

2. For such protection it is neither necessary nor economically practical to provide sufficient energy to raise or even maintain the temperature of beets on the pile face. The main objective is to provide sufficient energy to reduce the rate of emissivity of the beet so that during the nightly period of exposure the temperature of the beet will not go below the critical temperature of approximately 27° F.

3. Due to the slow rate of absorptivity and emissivity of a beet the protection attained varies directly with the time of application.

4. Dependable protection cannot be attained unless the beets received are freshly dug and the temperature change between them and the ground, from which they are taken, is small.

5. Uniformity and effectiveness of protection depends considerably on the uniformity of slope of pile surface. It decreases with the departure of the angle of radiation from that normal to the pile surface. Data indicate good protection of exposed beet surface, with reduced protection in the shadow behind the beets.

6. The application of 10 to 13 B.T.U. per square foot is sufficient to provide protection, providing all conditions are fairly uniform. However, non-uniformity of pile face and beet temperatures require an output of 20 B.T.U. per square foot in order to be more assured of protection.

ACKNOWLEDGMENT—Material used in this paper was obtained from General Electric Bulletin L D-16. Assistance was received from S. M. Heiner and Theodore Gessel of Amalgamated Sugar Company.

Beet Receiving and Storage

LYMAN H. ANDREWS[1]

This past harvesting season, one of the wettest encountered in years in our area, presented us with a new and difficult set of problems which had to be solved as quickly as possible. The rapid transition from 80 percent of the beets hand topped in 1947 to only 23 percent in 1951, with the balance, or 77 percent, harvested mechanically for our Company as a whole, is one of the most important factors to be considered. We had felt that we were about keeping pace with this transition in the method of harvesting, except at one or two factory districts where mechanical harvesting had progressed more rapidly. However, the delay caused by repeated storms during the harvesting season, coupled with the inability of growers to hire workers to sort beets from dirt on the harvester picking tables, resulted in the largest delivery of mud, rocks and trash ever before experienced. At most of our factories slicing was reduced below former standards because of inability to unload, flume and wash a sufficient quantity of clean beets to allow normal slicing.

The magnitude of this problem of dirt and rock removal can be appreciated when I tell you that at times at our Billings, Montana, factory this past campaign the total tonnage of rocks and chunks of mud taken by the rock wheel from 3,500 tons of beets exceeded 570 tons every twenty-four hours, this despite the fact that all but one of the thirty-four receiving stations at this factory is equipped with Rienks screens. The same problem is with us in years of extremely dry harvest when the hard clods are as troublesome to remove as the chunks of gumbo mud were this past season.

To get cleaner beets to our factory slicers we must constantly strive to improve methods and equipment at all three of the following places: first, in the field through grower cooperation; second, at the receiving stations by improving the screening devices; and third, at the factory with better trash catchers and rock wheel installations. The topic assigned to me will cover only the first two of these, except to say that the factory rock and trash catchers must be remodelled to handle many times the volume of dirt, trash and rocks than that for which they were designed.

Grower Cooperation

An analysis of the tonnage harvested in the Great Western territory by all harvesters in 1951 discloses that 80 percent was harvested with harvesters equipped with picking tables, and 14 percent by harvesters which deposited the beets in windrows after topping, while 6 percent were topped after being pulled from the ground and elevated directly to the truck or trailer cart. Even though most of the machine-topped beets are delivered shortly after being pulled and never have an opportunity to dry sufficiently for the soil to separate easily from them as they pass over the screening devices at the dumps and pilers, much can be done to decrease the amount of dirt delivered if more care is exercised by the grower.

The dissatisfaction caused by high tares and the consequent ill effect it has upon company-grower relations makes it imperative that both Company and grower organizations put on an effective campaign to encourage

[1] Northern District Manager, Great Western Sugar Company.

growers to eliminate as much dirt and trash as possible before delivering the beets to the receiving stations. The cost of hauling all of the dirt returned to the truck through the screen, besides that deducted for abnormally high tares, is a tremendous expense.

As an example, I cite the experience of one of our Montana growers who hauled 1,041 tons of beets and dirt to the station in order to deliver 592 tons of clean beets. He had brought in 43 percent, or 449 tons of dirt with his beets. A large part of this had to be hauled back to his farm for unloading at a double hauling cost. I know this is not unusual in other areas, for I saw some loads of beets being delivered to northern California factories late in November which were equal to the above example.

As a grower becomes more experienced in operating his harvester, he learns ways to improve its performance. There are countless examples of fine grower response to an appeal from company representatives to clean up unusually dirty beets. More encouragement and assistance should be given to those inventive individuals who develop ideas to eliminate clods and dirt. Beet growers are constantly improving the performance of their harvesters or offering valuable suggestions to the manufacturers for improvements they have worked out successfully for their conditions. The future market for harvesters will go to the manufacturer who improves his machine to best cope with the industry's problems.

Improvement of Screening Devices

Much can be done to improve the performance of our present receiving station equipment to take out more dirt and trash. So far the rubber Rienks screen seems to provide the best type of screen for our conditions. It is not entirely satisfactory, however, when the mud is of such consistency that it will stick to the rubber kickers. Up to this year we were of the opinion that rubber Rienks screen could not be plugged with mud. However, we have found it will operate for longer periods without plugging than the steel Rienks screens. Replacing steel Rienks screens with rubber will assist in improving the screening facilities.

Under dry to moist soil conditions, blowers located above the reverse rolls of the screen have proven quite effective in aiding in trash removal. When the beets are muddy and trashy the blower causes the screen to plug more quickly and it must be disconnected until the soil is drier. The past three seasons we have tried a blower located under the boom of the piler operated by a separate motor, which discharges a stream of high velocity air from below and through the beets as they are dropped from the end of the boom to the pile. This blows a surprising amount of leaves and weeds to the top of the beet pile, preventing them from going into the pile to cause heating and spoilage. The trash can be removed from the top of the pile prior to reloading for shipment to the factory.

Slowing down the speed of the Rienks screens to 110 or 115 r.p.m. has improved trash and dirt removal. This reduced screen speed is essential for rubber screens, since at speeds of 135 to 140 r.p.m. they tend to bounce the beets over the reverse rolls, carrying much of the leaves and trash with them.

Widening and lengthening the screen to allow beets to spread out in a thin layer in passing over the screen will provide better screening. The

longer and wider Rienks screens which have a set of two reverse rolls in the middle of the screen, with a drop to another set of forward rolls and a second set of reverse rolls, provides better screening. These alterations, while possible, will require time and expensive changes if applied to the present receiving and piler equipment.

A rubber belting drape placed on top of the steel Rienks screens, extending to the end of the last forward roll, has aided in dirt and trash removal by keeping the beets down on the screen and in rolling them over as they pass over the screen. One of our factory organizations reports better results if the drape extends down over the reverse rollers. Unless care is used this will force more small beets thfough the Rienks screen and is one of the reasons why this longer drape arrangement cannot be used successfully with the rubber Rienks screen.

At smaller stations where the deliveries are easily handled without undue delay, the flow of beets from the beet hopper to the screen can be reduced sufficiently to prevent them from piling up on the screen so deeply that poor screening results. The reduction in the percent tare will compensate for an additional minute required to elevate a load of beets. During periods following a storm, when deliveries are slower and trouble is experienced in keeping the screen clean, the flow of beets up the piler elevator to the screen should be reduced by slower dumping of the truck or, preferably, by cutting down the size of the opening from the beet hopper to the elevator by an adjustable gate.

In 1948 a flail-type beater was installed above a piler Rienks screen in an attempt to knock off adhering leaves and dirt from the beets. It was not successful, even though varying speeds and sizes of flails were used, rotating with or against the flow of beets across the screen. When the rotation of the flails was rotating to knock the beets in the direction of the flow of the screen, it assisted them off the screen too rapidly for good screening. When rotated against the screen's rotation, it tended to cause the beets to pile up and prevented effective screening.

Automatic and Mechanical Dirt Reclaimers

Practically all of our beet dumps and all of the Silver pilers have dirt-catching devices installed under the elevator belts to automatically return to the grower's truck most of the dirt dropped from the belts while his load of beets is being elevated. On most of our pilers the present dirt reclaimers do not extend low enough to prevent serious losses of dirt. Engineers from both the manufacturer and our company are working on designs to improve piler dirt reclaimers on the new models as well as for those now in the field whose reclaimers proved inadequate in a harvest such as the past one.

Central Taring

The most controversial issue during the harvesting and receiving of a beet crop in recent years is the question of determining an accurate tare. Fifteen years ago, in an attempt to improve upon the method of taking tares at the individual stations, the company decided to try out the idea of bringing all tare samples at the end of each day to a central tare house located at the sugar factory.

The first tare houses used men equipped with hand brushes to clean the beets. A few factories tried power-driven rotary brushes. In 1946 the shortage of men to operate the tare houses induced the introduction of beet washers to replace the hand cleaning, and automatic top taring machines to replace the beet knife for trimming the crowns of poorly topped beets; also, the installation of hot air dryers to remove the excess water from the washed beets. These improvements, with the two electric self-registering scales to weigh the dirty and clean samples, eliminated most of the hand work formerly required and received the approval of all concerned in the determination of a proper tare.

The rotary metal beet washer is a perforated steel drum enclosed in a housing open at both ends. It is 2 feet in diameter and 2 feet, 6 inches long and revolves at 4½ r.p.m. with water spray jets inside discharging water against the beets at 125 pounds pressure supplied by a 2-inch pump. The uncleaned sample is put in one end of the washer and, when clean, discharged from the opposite end into a perforated metal basket. Under normal conditions each washer has a capacity of from 45 to 50 samples per hour.

The use of beet knives in the hands of individuals to take the top tare was subject to human judgment, sometimes questioned by one party or the other, so automatic rotary topping machines were made and installed. All beets now are topped usually before washing by rotary beet crowners made of a bronze casting, the center portion of which is cone-shaped, carrying high carbon steel knives to trim the large-sized beets to the exact angle. The outer rim of the rotor is a flat surface bearing knives protruding slightly which remove the crowns of smaller beets from which the tops are to be cut off squarely. Each crowner revolves at a speed of 700 r.p.m. and is powered with a one-horsepower electric motor.

The perforated metal tare baskets are 18 inches in diameter and 12 inches high, all balanced to weigh exactly the same. They carry the wet washed sample through a sloping 12 to 15-foot drying tunnel requiring from 5 to 6 minutes to reach the clean weight scale. Steam or gas heat is used to pre-heat the air drawn from the outside, after which a buffalo heater fan rated at 6610 C.F.M. is used to circulate the hot air through the tunnel, removing only the free moisture adhering to the outside of the beets.

The average tare house which expects to work 900 tare samples per day will require 6 men, 2 scales, 2 washers and 2 crowners for efficient operation.

At those factories where individual sugar analyses are to be determined, the clean tare sample is immediately transferred to the beet laboratory.

Storage of Beets

In 1947, an unsatisfactory experiment in which we tried ventilating factory storage piles located over flumes is our only experience with ventilation to control storage losses. Because of our relatively short storage period, we have felt that the returns on the investment did not justify the expense involved. During the past five years the average number of days beets were stored varied from fourteen in 1948 to twenty-six days in 1950. This past year beets were stored an average of approximately twenty days.

Storage losses may be reduced and controlled to a great degree by following a few simple precautions. During the building of a storage pile, the piler should not be moved more than three to four feet for each complete swing of the boom. This will keep the top of the pile smoother. It will reduce the amount of dirt and trash deposited in one spot as compared to that when longer moves are made. The dirt and trash spots will also be nearer the top of the pile. At the first signs of hot spots developing, it is easier to dig down to them from the top of the pile for exposure and aeration, and if this is done in time it will stop further spoilage.

If the boom is swung to the outside rim of the pile whenever unusually dirty or trashy loads are received, it will decrease the danger of spoilage.

Spoilage losses in piles should decrease proportionately in the future with the increase of mechanical harvesting and its improvement in trash and dirt elimination. Two of the most serious causes of pile spoilage have been the hot, wilted beets and the frosted or frozen beets loaded from field windrows. With the further elimination of hand toppers and the replacement of harvesters which place beets in windrows, these sources will no longer be a factor in a few years.

The height and shape of the storage pile are undoubtedly important factors in decreasing storage losses. One of the serious losses which occurs in any pile, whether ventilated or unventilated, is in the beets exposed to the elements on the sides and top of the pile. More tonnage in relation to the surface exposed can be stored in a high narrow pile than in one with the same cross sectional area built wider and lower. For example, a pile 90 feet wide at the base and 22 feet high has 17 percent less surface exposed on the sides and top for the same tonnage stored than one with a base of 120 feet and 14 feet high. In normal years the worst beets to process are those from the outside of the piles. All other conditions being equal, to cut down on this loss is a saving.

There are those who believe that the natural exchange of air between the outside and inside is facilitated by the high narrow pile, as compared to the low, wide one. More information is needed to show the rate of exchange of air under differences in temperatures between the inside and outside of storage piles.

Daily examinations of the top of the piles will detect the first signs of spoilage. Trenching down to the spot, which usually starts four to six feet below the surface, will generally retard any further heating. If this does not stop the heating, that part of the pile should be reloaded at once. Heavy shrinkage losses of sugar and weight have been prevented by first reloading the early piled ends of the storage piles if they were put in during a period of unseasonably hot weather. The same procedure should be followed on the last end piled, if frost has damaged some of the beets which went into storage. The cost of transferring reloading equipment is minor as compared to spoilage losses sustained by waiting.

If I have disappointed you in not offering some startling new methods to improve those we are now following, let me remind you that most of the strikingly successful innovations have come from doing the old things better than they have ever been done before.

Experimental Presswheels

JAMES H. FISCHER[1]

The Beet Sugar Development Foundation has experimented with hundreds of types of presswheels since the day of the Foundation's inception in 1945. The majority of this work has been conducted in cooperation with Colorado A & M College. Theories regarding presswheels have been thoroughly investigated and various designs, both commercial and experimental, have been tested side by side under identical conditions. Objective in this work was the location of a simple type of presswheel adaptable to commercial drills which would improve field germination in the majority of field conditions. A description of the many types used is far too long to include in this summary.

It has been theorized that improved field germination is obtainable through a compaction of the soil immediately around and below the seed zone to improve capillary action of the subsoil moisture. This, in part, is accomplished by the commercial concave presswheels by a side pressure immediately around the seed zone and the creation of a loose soil condition immediately above the seed.

This compression also can be accomplished by pressure from immediately above the seed but at the expense of a depressed profile which creates a pocket in which moisture can lodge and, subsequently, create a crust condition. This was the observation with a standard convex tire similar to those found on children's wagons, etc.

Early experience with the furrow-former wheel exposed a theory which was recently developed into a presswheel combination which shows considerable promise. Early trials with such type presswheels were conducted with semi-commercial presswheels of a v-shaped profile which were not of a size immediately adaptable to our beet and bean drills. Excellent results, however, were obtained which encouraged thinking toward a simple type of v-shaped presswheel.

In 1950, the idea was conceived that a standard concave presswheel would make an ideal rim into which a rubber tire filler of any shape or profile could be inserted. In cooperation with the Gates Rubber Company, the Beet Sugar Development Foundation had three different profile designs of both semi-pneumatic and solid type moulded at the Gates Rubber Company in Denver, Colorado.

These prototype rubber filler tires were received at a date too late to obtain satisfactory "spring condition" results but the tests conducted were satisfactory to the point of warranting further studies.

In 1951, approximately 500 of these semi-pneumatic filler tires (of three profile shapes, elliptical, Semi-V and V) were fabricated for extensive test work in a fair cross-section of our beet-growing territories. These were sent out accompanied by a survey form on which comparative data with the standard presswheel was to be recorded.

From more than 100 surveys conducted in Washington, Idaho, Utah, Montana, Wyoming, Nebraska, Colorado, Minnesota, California and Kansas, the overall increase in emergence with this type of presswheel was 14.2 percent, or 114.2 percent of standard. The above data was compiled from more than 1,000 100-inch counts in the field and a comparable number

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[1] Secretary-Treasurer, Beet Sugar Development Foundation.

Figure 1.—Convex rubber tire filler mounted on standard presswheel. Note how drag-chain mulches indentation created by pressing action.

of counts on the adjacent standard presswheel. The total average increase in emergence boils down to an increase of six plants per each 100 inches of row. This figure is highly significant.

There are cases where emergence was depressed by this type of experimental wheel. Such surveys have been taken into consideration on an equal weight basis with those which showed increased emergence.

It is concluded that, in the territories where there is marginal rainfall, the convex type of presswheel is advantageous in procuring an improved stand. In territories of adequate rainfall and where planting is necessary in wet conditions, a rubber presswheel will not show an advantage. In such conditions, the operator would become perplexed with mud clinging to the rubber presswheel. It is theorized that in such conditions of high moisture, it is only necessary to compact the soil around the seed sufficiently to have the soil physically contact the seed in the soil and presswheels are of less consequence than in the territories of marginal rainfall.

Sugar Beet Weeder

R. D. BARMINGTON[1]

In an effort to develop and study a new principle in mechanical weed control in sugar beets, the Mechanical Engineering Section of the Colorado Experiment Station has constructed an experimental model of a two- or four-row weeder. This machine, because of its unique action, not only effects a good measure of weed elimination, but also provides a good mulch around the plants.

With adjustment of the experimental model of the machine for use on two rows at a time, 23.6 percent of the weeds and 13.7 percent of the beet seedlings were removed. Adjusted for use on four rows, the machine

Figure 1.—Close up of "baskets" showing how the spring tines intermesh over the row.

removed 40.1 percent of the weeds and 16.4 percent of the beets. Action of the machine in "selecting" between weeds and beets is based on the fact that beets have stronger roots from the time of emergence. This brings up the possibility of using the machine on other root crops.

Weeding is done by flexible tines, mounted on power-driven circular frames, which revolve in a cycloid motion through the beet rows. Arrangement of tines and method by which a row is weeded is similar to that which can be visualized by moving an egg beater in a lateral motion while revolving the beater blades.

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[1] Associate Mechanical Engineer, Experiment Station, Colorado A & M College.

Figure 2.—Unit set up to operate over four rows.

Figure 3.—Unit set to operate over two rows. The teeth of the "baskets" rotate into the row on each side, then pull out producing a "cycloid" pattern on each side.

Development of the newest model comes from an earlier, single-row type which appeared to have practical adaptation. The new model consists of four circular mounts (or "baskets") made up of eight tines each and arranged on a wheeled frame. By adjustment, these can be fitted to operate singly to weed four rows, or in intermeshing pairs to weed two rows at a time. One of the chief advantages of the paired adjustment is the gentle weeding action around the plants, which in turn speeds handwork.

The machine can be operated at about 2½ to 3 miles per hour in second gear on a Ford tractor. By changing gear ratios a more severe action or treatment can be achieved, depending upon the size of beets and the condition of the soil. With the eight tines per basket, a tine goes through the row every two inches when the tractor is in second gear.

Best results have been obtained when the beets were in the two-leaf stage. The size of the beets determines the operating speed and whether the machine should be used as a two-row or four-row unit.

The Bye-Hoe—A New Row-Crop Cultivator

ARTHUR JOHNSON[1]

For many years the peatland farmers of the Sacramento-San Joaquin Delta region have used a "Spinner" cultivator for weeding and mulching the soil between the beet rows. In the Bye-Hoe, Byron Peters of Stockton, California, has adapted the principle of this spinner to a row-crop cultivator for use in all types of soil.

The Bye-Hoe can be attached to any conventional cultivating tractor, by mounting it in the normal position of conventional cultivating tools. Figure 1 shows the unit as adjusted to cultivate bed-planted beets with a spacing of 12 inches x 28 inches. The hoes in the center of the bed cut parallel with the ground while the hoes at the extreme outside of the beet rows are bent to fit the shoulder of the bed. The hoes are held rigidly in channels in the hub and can be changed by removing one bolt in each hoe. The entire hub, with hoes attached, is held on the 1¼-inch shaft with two bolts.

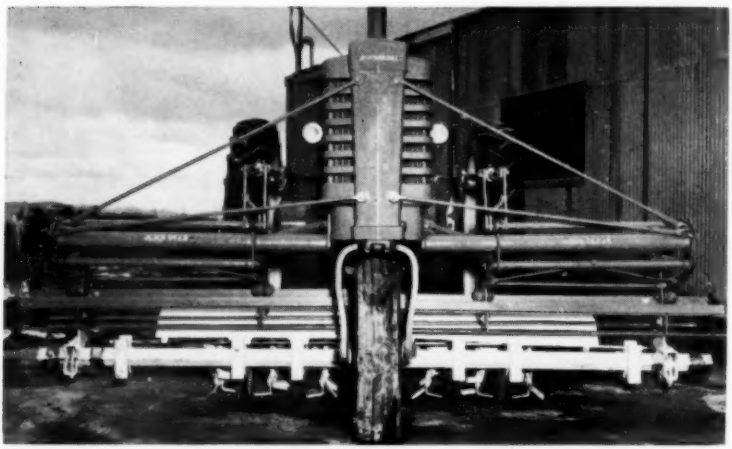

Figure 1.—A front view of the Bye-Hoe mounted beneath the tractor. Note the setting of knives to cultivate both the center and edges of beds.

The rotating cultivator assembly is power-driven from the power take-off at a rate of 50 to 150 r.p.m. The 15 inch free-turning discs are located on either side of the rotating hoe assembly. The hoes, which turn in a 14 inch diameter, will mulch the earth to a depth of six inches. Weeds and grass roots are disintegrated by the sharp, knife-edged hoes. The discs make a clean line between the cultivated ground and the narrow seedling row and protect the small seedlings. Since the seedlings are protected, cultivation can start immediately upon emergence.

[1] District Agriculturist, Holly Sugar Corporation, Stockton, California.

Figure 2.—The dirt has been moved away to show the narrow plant row which can be left.

The Bye-Hoe is ideal for doing pre-thinning cultivating on either flat or bed-planting. The mulched earth is replaced so that the ground surface is left smooth, with no ridges to dry out or break off. Figure 2 shows the earth pushed away to expose the narrow plant row which can be left. The machine is adjustable for width of cut and depth of mulching and can work to within 3/8 inch of the seedling row. It is adaptable to any row width or any combination of row widths.

By removing the discs and pushing the hoe units close together on the shaft, the Bye-Hoe will mulch a solid band up to three feet wide or more, depending upon the type of ground and on the ability of the tractor to furnish the necessary power. This is an excellent method of preparing the seed bed, and, by attaching the planter behind the tractor, mulching and planting can be accomplished simultaneously.

This report is presented, not as a statement of machine preference, but as a statement of a new principle in cultivation which has demonstrated application to the culture of sugar beets.

Spring Tools

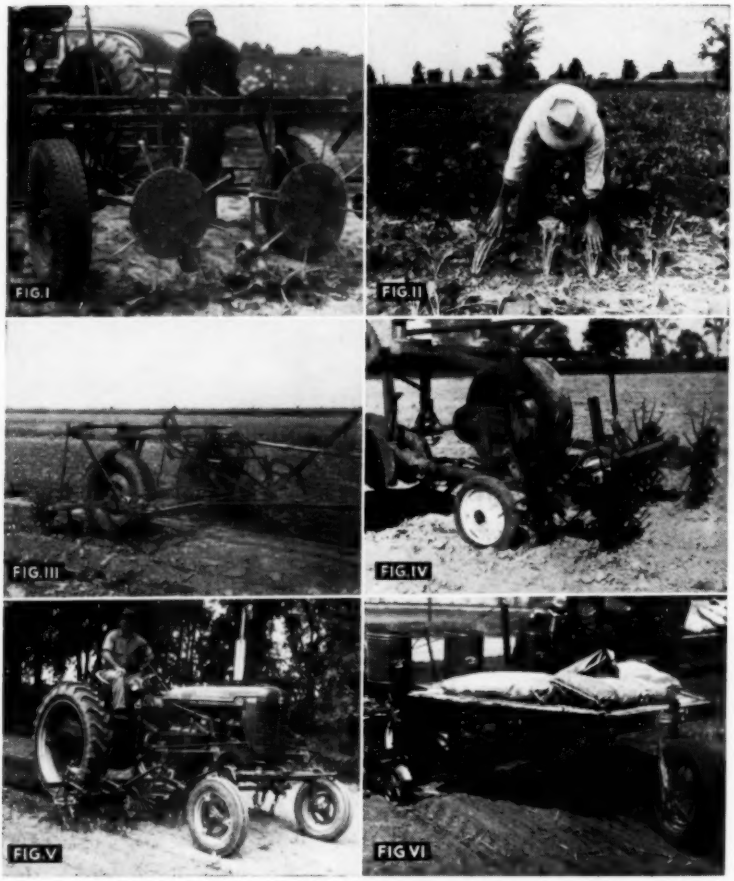

Figure 1.—Heavy duty heads for large beets.

Figure 2.—Results of use of machine thinner on large, thick beets.

Figure 3.—Thinner with chain and sprocket drive and split-v-shieves for speed variation.

Figure 4.—Application of counter-rotating head principle to the old two-row Dixie Cotton Chopper. (Application by C. M. Hansen, Michigan State College.)

Figure 5.—Ground-driven thinning units used simultaneously with cultivating tools.

Figure 6.—Trail cart for beet drill which carries several hundred pounds of fertilizer from which a man riding the cart may refill the fertilizer cans without stopping or reducing speed.

Figure 1.—Close-up of "Cultro" in weedy field at Fort Collins, Colorado. (This sequence of pictures depicts effectiveness of machine thinning procedure.)

Figure 2.—Result of cultivation with rotary cultivator and duckfeet.

Figure 3.—An in-the-row weeding operation with "cycloid weeder."

Figure 4.—First thinning operation with a down-the-row machine using 8-spoke heads.

Figure 5.—Second thinning operation using 16-spoke heads.

Figure 6.—Seventeen days following the operation in Figure 5 and a minimum of hand work with long handle hoes, this clean field with good stand resulted.

Marihart Thinner

Figure 1.—Side view of Marihart thinner mounted on a conventional tractor. Set up for four-row operation.

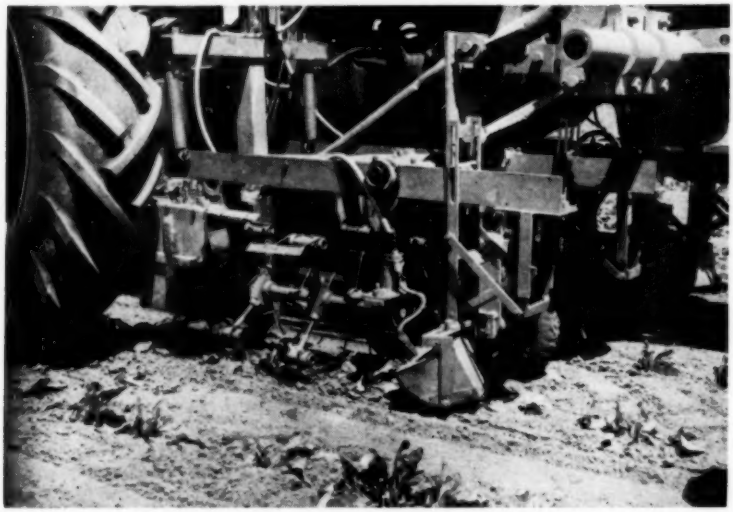

Figure 2.—This view shows the "electric eye" which picks up the light reflection from a plant and relays an electrical impulse to a control box which governs the actual hoeing through a system of sprockets, clutches, electrical controls and spring-mounted cutters. The hoeing will take place on both sides of the plant to be left.

Figure 3.—This rear view of the Marihart thinner shows the drive system, generator and control boxes which activate the selective hoeing accomplished by this machine.

A Measure of 1951 Mechanical Thinning

JAMES H. FISCHER[1]

The Beet Sugar Development Foundation in 1951 measured the progress of mechanical thinning methods in our many beet-growing areas. Reports were received on a total of 564,000 acres. In this summary, it is assumed that the balance of the 1951 acreage not reported received no machine thinning whatsoever.

Survey forms in a quantity sufficient to supply each factory district were forwarded to the sugar companies. The form requested tabulation of acreage worked by the various types of positive machine thinning tools and the many types of flexible tined weeders. The total acreage worked with such machines as the Silver (Great Western) down-the-row machine, the Dixie two-row converted, the Dixie 1950-51 model, the B. & P., the Eversman with discs and the Eversman with small hoes totalled 88,556 acres. In addition to the above figure, 29,079 acres were cross-blocked and 46,475 acres were cross-cultivated.

Applying the term "positive stand reduction tool" to the units listed above, it can be said that 164,100 acres had some type of positive stand reduction tool used on the 1951 sugar beet crop.

It is a known fact that tools of spring tine or harrow design are advantageous to stand reduction as well as weed elimination. This report indicates that such tools were used on 89,768 acres. Assuming that spring-tined and harrow tools were used on approximately 25 percent of the acreage worked with a down-the-row or across-the-row thinning unit, it is safe to assume that 231,000 acres have had some kind of mechanical spring tool used on the 1951 crop. This figure represents 40 percent of the reported acreage or within the neighborhood of one-third of our total 1951 crop.

It is encouraging to note the large number of growers who are now using a positive stand reduction tool. It has been proven over and over that such an operation will reduce the time requirement of spring labor by one-third. This time reduction has not been effectively felt in a dollars and cents value by the growers but has definitely improved labor attitude and improved the hourly wage rate. Further developments will undoubtedly result in a reduction of spring costs to the sugar beet grower.

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[1] Secretary-Treasurer, Beet Sugar Development Foundation.

CHEMISTRY
AND
FACTORY OPERATIONS

The Improvement in First Carbonation Station Operations at Moorhead, Minnesota

J. F. PRICE[1]

At the Moorhead factory, which has now operated four campaigns, we have the conventional continuous first carbonation station as furnished under the Dorr patents at the time the plant was built.

Ever since the termination of the first campaign in 1948 we have felt that there was a large field for improvements of the juice as it was leaving the Dorr thickener, in regard to color and non-sugars, and for the bettering of the results at the first carbonation filtration station.

We have at Moorhead a continuous Silver diffuser of the chain and basket type in which the retention time for cossettes is relatively high. This long retention time may have been a contributory cause for the rather dark juices resulting from the first carbonation when it was carried out in the usual manner.

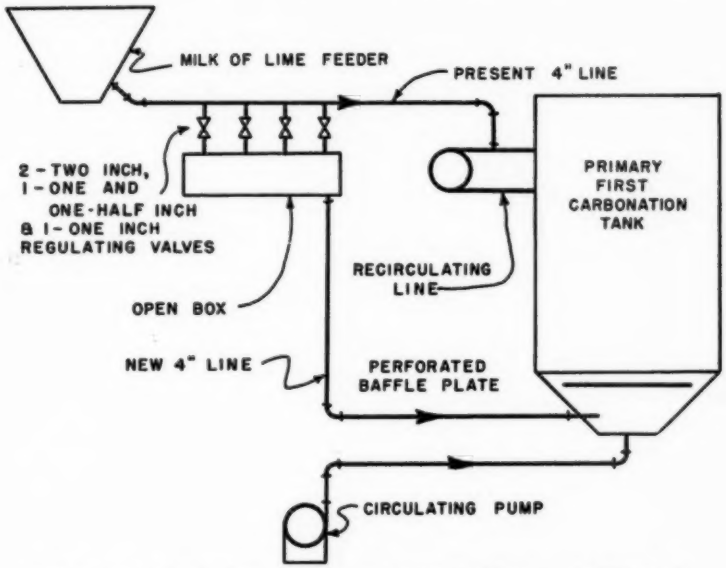
In order to improve the juice color and the settling rate, we considered a change in the recirculation ratio. We found, however, that when making a change in either way from the usual 750 to 900 percent recirculation a poorer settling of the sludge resulted and the filtration of the juices became difficult, so any thought of changing the ratio was abandoned. It is generally agreed that a recirculation ratio of 7.5 to 10.0 should be maintained and that more harm will result from lowering the ratio than from increasing it.

Another possibility for improving the color of the juices was in lowering the retention time in first carbonation. It is generally conceded that the optimum retention time is about 20 minutes, with about 11 minutes in the primary tank and 9 minutes in the secondary tank, whereas at Moorhead we had a total retention time of approximately 31 minutes. The most feasible way to cut the retention time was to lower the circulating line between the tanks, thereby cutting down the volume capacity of the tanks. Due to physical obstructions, however, it was impossible to lower the mentioned circulating line appreciably.

Consideration was next given to certain changes within the carbonation tanks. In the secondary tank there is a vent pipe leading from the center of the deflector over the juice outlet to above the circular baffle plates in this tank. It would seem possible that the newly limed juice from the overflow from the primary tank could short circuit through the vent pipe to the juice outlet, thus causing some under-carbonated juice to be discharged to the Dorr tank. In order to check on this possibility, we closed the vent line on one of the secondary tanks, while the other secondary tank remained unchanged with the vent open. We have operated with and without the vent pipe open for two campaigns, alternating between the secondary tanks as it became necessary to change them and no special difference has shown up.

In order to prevent channeling of the juice between the inlet in the bottom of the primary tank and the circulating line to the secondary tank, we installed a perforated baffle plate of approximately 5 feet diameter

[1] Superintendent, American Crystal Sugar Company, Moorhead, Minnesota.



MILK OF LIME TO FIRST CARBONATION – MOORHEAD

horizontally in the center of the tank at about the height where the bottom cone joins the walls of the tank. This disperses the juice and gives a much more evenly distributed flow of the juice through the primary tank.

During the first two campaigns of operation the alkalinity of the primary tank proved to be substantially lower than the alkalinity of the secondary tank, which is in agreement with the fact that all the raw juice enters carbonation at the bottom of the primary tank together with the recirculating juice from the secondary tank. It was our thought, however, that the difference in the alkalinity between the two tanks was too great and for that reason we decided to add a small amount of lime to the primary tank.

As we did not know just how much lime was needed, we arranged a manifold take-off from the regular lime feed line with ¾ inch, 1 inch, 1½ inch and 2 inch valves. These valves all discharge into a funnel attached to a 4 inch line leading to the bottom of the primary tank. With this arrangement of multiple valves it was possible to obtain a considerable range and a fairly close control in the lime addition.

We proceeded cautiously with the lime addition and observed that with fresh beets and with the ¾ inch valve open we would obtain an alkalinity in the primary tank slightly under the alkalinity in the secondary tank and that at this point we would get the fastest settling rate, the clearest juice, and the best filtration on the first carbonation filters. After some experimentation, we arrived at a figure of .005 alkalinity below the secondary tank as the proper place to maintain the alkalinity in the primary tank.

The following table gives our operating results for the first four years,

Table 1.

	Alkalinities		Soda Ash Addition per ton beets	Second Press Juice	Lime Salts Evap. Thin Juice	First Liquor
	1st press	2nd press				
1948	.089	.022	.72	.095	.084	
1949	.104	.022	.98	.103	.066	.035
1950	.102	.027	.60	.060	.046	.029
1951	.077	.022	.22	.060	.036	.018

the first two without split lime addition, and the last two with split lime addition. The results would show an improvement in the lime salts, which have decreased considerably in spite of a decrease in the soda addition. Improvement in the filtering and washing qualities of the lime sludge was indicated by the decrease in requirement of wash water—percent on cake while maintaining substantially the same losses.

Table 2.

	% Press Wash Water on Cake	Press losses % Sugar on Beets
1948	128	.10
1949	96	.04
1950	90	.05
1951	80	.04

In the reviewing of the tabular date above, we realize that there can be many other contributing factors which may have improved our operating conditions, but it is felt that the split lime addition has been a contributing factor in improving our local operating conditions.

Table 3.

First Carbonation Station Equipment

1—Primary tank 11′—0″ diameter x 13′—9″ above gas distributor—overall height 29′—7″ total capacity 11,750 gal.

2—Primary tanks 11′—0″ diameter x 29′—7″ overall height. Juice level 20′—6″ total capacity gallons 13,000.

Note: (Only one secondary tank is used at a time) 3′—6″ difference in head between the two tanks.

1—Byron Jackson pump 5,000 GPM at 11 ft. head
700 GPM juice flow gives recirculation ratio of 7.5 to 8.

Adaptation of the Spectrophotometer to the Analysis of Water

H. M. Bauserman and Rob Roy Cerney, Jr.[1]

General Procedures for Flame Spectrophotometer Analyses

The Beckman model DU quartz spectrophotometer is set to measure the intensity of one of the characteristic wavelengths of light produced by exciting the elements in question in an oxygen-natural gas flame.

When all other conditions are kept constant the light intensity of each specific wavelength is proportionate to the rate of introduction of the element into the flame. The rate at which a solution of the element is introduced is kept constant by forcing it to pass through a capillary tube under a constant pressure differential by means of an air aspirator. The light intensity must then be proportionate to the concentration of the element in the solution. Previous calibration of the capillary tube using standard solutions of varying concentrations makes it possible to relate the light intensities of these known standards to the light emitted from like elements in the water under examination.

Certain few ions are of such a character that they affect somewhat the light intensity emitted by certain elements. The following procedures are designated to overcome such interferences. All waters must be first filtered. This conforms to the Association of Official Agricultural Chemists' procedure and is necessary to prevent plugging of the atomizer tip. One hundred ml. of filtered water will be more than adequate for the eight constitutents listed below. Avoid dust and lint particles from towelling in the solution to be tested.

The following instrument settings are constant for all flame analyses: sensitivity 2½ turns from full clockwise, gas 4 cm. before turning on oxygen, air 25 psi and decimal selector switch 0.1.

Determination of Sodium and Calcium

Standard Curves. Prepare two standard solutions: one containing 2,000 ppm. Na as NaCl, the other containing 2,000 ppm. Ca as $CaCO_3$ dissolved with HNO_3. By diluting the Na standard prepare a series of 9 solutions ranging from 0-200 ppm. Na at intervals of 25 ppm. To each of these solutions add $MgCl_2$ for 20 ppm. Mg, KCl for 15 ppm. K, and 100 ppm. Ca.

By diluting the Ca standard prepare 4 series of 9 solutions each ranging from 0-200 ppm. Ca at intervals of 25 ppm. To the first series add no Na, second series add 50 ppm. Na, third series add 100 ppm. Na, and fourth series add 200 ppm. Na. Add Mg and K for 15 ppm. of each in all 36 solutions. The purpose of using 36 standards for the Ca calibration is to determine the extent of the distortion of the Ca determinations due to the presence of sodium. Read all the standards at the appropriate instrument setting (given below) and obtain the points for 5 calibration curves—4 for Ca and 1 for Na.

In the preliminary investigation, we produced 9 calcium curves, each with different amounts of Na, and 9 Na curves, each with different amounts of Ca. Since the effect of calcium on sodium is negligible, only one sodium curve is necesary. Although sodium appreciably affects the Ca calibration, instead of using 9 curves we found that 4 curves were adequate, these four

[1] Experimental Chemist and Chemist, respectively, American Crystal Sugar Company, Rocky Ford, Colorado.

being the Ca standards containing 0, 50, 100, 200 ppm. Na. Of the common anions, bicarbonate alone, at the concentrations greater than 100-200 ppm. depresses Ca emission. If necessary to decrease the bicarbonate concentration add acid and boil the sample.

Analytical Procedure. For sodium the instrument settings are as follows: Wavelength 590 mu, red phototube in place, no filter, oxygen 42 inches of water, and slit width 0.07 mm. Introduce a standard containing 200 ppm. Na only and balance the instrument at 100 transmission units. Then read the percent transmission of a solution containing 100 ppm. Na only. This reading serves as a control, which should be repeated often while analyzing samples and should not vary more than $\pm$ 0.3 transmission units during the analyses to assure that conditions have remained constant. Rinse and fill a 5-ml. Beckman beaker with the original filtered water, place under the atomizer tip and record the resulting transmission units. Dilute if necessary to bring the readings within the range of calibration.

The settings for Ca are: Wavelength 556 mu, blue phototube in place, didynium filter in place, oxygen 32 inches of water and slit width 0.30 mm. Follow the Na procedure except to substitute a solution of 200 ppm. Ca only for setting the transmission at 100. Read a solution of 100 ppm. Ca only for the curve control. The allowable tolerance is again $\pm$ 0.3 transmission units. Replace the beaker containing the unknown under the atomizer tip and determine the transmission units. Having the resulting transmission units at both appropriate wavelengths, find the ppm. sodium then ppm. calcium from the proper calibration curve, taking into account the presence of sodium when using the calcium curves.

Determination of Potassium

Standard Curve. Prepare a standard KCl solution containing 400 ppm. K. By diluting this primary standard prepare a series of six standard solutions ranging from 0 to 100 ppm. K at intervals of 20 ppm. Each standard should contain also 50 ppm. Mg, 100 ppm. Na, and 100 ppm. Ca. The points on the curve are determined by reading the above standards at the proper instrument settings (given below). It was found that varying the concentrations of the other constitutents had negligible effect on the potassium reading.

Analytical Procedure. The instrument settings: Wavelength 768 mu, red phototube in place, no filter, sensitivity 2½ turns from full clockwise, gas 4 cm. before turning on oxygen, 36 inches of water, air 255 psi, slit width 0.050 mm. Introduce a standard containing 100 ppm. K only and set the instrument at 100 tranmission units. Then, for a control, read the percent transmission of a solution containing 40 ppm. K only. This curve control reading should not vary more than $\pm$ 0.3 transmission units during an analysis. Introduce some of the same 5 ml. portion that was used for Na and Ca. Note the transmission units and obtain the ppm. K from the standard curve. Again retain the solution for later use.

Determination of Magnesium

Standard curve. Prepare a standard solution containing 500 ppm. Mg as $MgCl_2$. By diluting this primary standard prepare a series of 5 standard solutions ranging from 0 to 100 ppm. Mg at intervals of 25 ppm. Each standard should contain also 40 ppm. K, 100 ppm. Ca, and 100 ppm. Na. The points on the curve are determined by reading the above standards at

the proper instrument settings (given below). It was found that the varying of the concentrations of the other constituents had a negligible effect on the magnesium determination.

Analytical Procedure. The instrument settings: Wavelength 383 mu, blue phototube in place, no filter, sensitivity 2½ turns from full clockwise, gas 4 cm. before turning on oxygen, oxygen 56 inches of water, air 25 psi, slit 0.70 mm. Introduce a standard containing 100 ppm. Mg only and balance the instrument at 100 transmission units. Then, for a control, read the percent transmission of a solution containing 50 ppm. Mg only. This curve control reading should not vary more than $\pm$ 0.1 transmission units during an analysis. Introduce a portion of the same sample that was used for Na, Ca and K. From the transmission units found, determine the corresponding ppm. Mg from the calibration curve.

Determination of Sulphates

Standard Curves. Prepare a standard solution containing 1,000 ppm. SO_4 as K_2SO_4 (I). Also prepare two standard solutions of barium—one containing 500 ppm. SO_4 equivalent as $Ba(NO_3)_2$ plus 1 gram sodium acetate per liter (II); the other containing 250 ppm. SO_4 equivalent as $Ba(NO_3)_2$ plus 0.5 gram sodium acetate per liter (III).

Two calibration curves are advantageous, one curve for 200 to 500 ppm. SO_4, the other for 0 to 200 ppm. SO_4. By diluting (1), prepare a series of secondary standards ranging from 200 to 500 SO_4 at intervals of 50 ppm. To ten ml. of each of these sulphate standards add 10 ml. of (II). Warm in a stoppered flask. Cool and filter a portion into a 5-ml. beaker. There are then seven solutions containing $Ba(NO_3)_2$ ranging from 150 to 0 ppm. SO_4 equivalent. The excess Ba is read on the flame photometer. By diluting (I) prepare another series of secondary standards ranging from 0-200 ppm. SO_4 at 25-ppm. intervals. To 10 ml. of each of these solutions add 10 ml. of (III), warm in a small stoppered flask and treat similarly to above. The concentrations are shown in the accompanying table:

Table 1.

For the 200-500 ppm. SO_4 curve:									
ppm. SO_4 in secondary standard	200	250	300	350	400	450	500		
ppm. SO_4 after 1:1 dilution	100	125	150	175	200	225	250		
ppm. SO_4 equivalent as $Ba(NO_3)_2$	250	250	250	250	250	250	250		
ppm. SO_4 equivalent in excess	150	125	100	75	50	25	0		
For the 0-200 ppm. SO_4 curve:									
ppm. SO_4 in secondary standard	0	25	50	75	100	125	150	175	200
ppm. SO_4 after 1:1 dilution	0	12.5	25.	37.5	50.	62.5	75.	87.5	100
ppm. SO_4 equivalent as $Ba(NO_3)_2$	125	125	125	125	125	125	125	125	125
ppm. SO_4 equivalent in excess	125	112.5	100.	87.5	75.	62.5	50.	37.5	25.

The instrument settings are as follows: Wavelength 831 mu, red phototube in place, no filter, sensitivity 2½ turns from full clockwise, gas 4 cm. before turning on oxygen, oxygen 34 inches of water, air 25 psi. For the 200 to 500 ppm. SO_4 series, adjust the slit width to 0.50 mm. and balance at 100 transmission units using the secondary SO_4 standard which originally contained 200 ppm. SO_4. For the 0 to 200 ppm. SO_4 series, adjust the slit width to 0.52 mm. and balance at 100 transmission units using the secondary SO_4 standard which originally contained 0 ppm. SO_4.

Analytical Procedure. If sample contains more than 500 ppm. SO_4 dilute to 200 to 500 range. Pipette 10 ml. of the sample water into a 50-ml.

flask. If sample contains 200 to 500 ppm. SO_4, add 10 ml. of (II). If sample contains 0-200 ppm. SO_4, add 10 ml. of (III). Stopper, warm and allow to stand, then filter. Introduce a portion of this filtrate into the flame atomizer. Record the transmission units and obtain the ppm. SO_4 from the proper calibration curve.

Procedure for Chlorides—Tentative

The method is similar to the procedure for sulphate determination. To a series of standard chloride solutions add a measured amount of standard silver nitrate which is an excess. Filter and read the excess silver on the spectrophotometer. The instrument settings are as follows: Wavelength 338.3 mu, blue phototube in place, no filter, sensitivity 2½ turns from full clockwise, gas 4 cm. before turning on oxygen, oxygen 56 inches of water, air 25 psi, slit width 1.0 mm. The curve should extend to 100 ppm. chloride on original sample. The detectability of silver is approximately the same as barium.

General Procedures for Absorption Spectrophotometer Analysis

Standard procedures are used to develop the colors of the ions in question. The absorption of specific wavelengths of light is measured using the spectrophotometer. It is possible to select any wide or narrow band from the entire visible or ultraviolet portion of the light spectrum. Critical selection of a narrow band of wavelengths permits analyses with a minimum of interference and high precision. Calibration curves made from standard samples expedite and simplify the analytical procedure.

All colors to be measured are produced by methods as described in *Methods of Analysis*, Association of Official Agricultural Chemists, 6th edition, 1945. All instrument settings reported here were found by experiment. Many wavelengths were tried until one was found which gave maximum differences between those standards which fall in the range of the unknown. At the same time the wavelengths chosen were such as to give reproducible results with duplicate standards.

Procedure for Nitrates

The color to be measured is produced by the reaction of nitrates with phenodisulphonic acid. The intensities of colors produced by nitrate solutions ranging from 0 to 0.10 mg. of NO_3 are used to prepare a standard curve. The intensities of color produced by unknown solution, similarly treated, are compared with the standard curve to determine the quantity of nitrate present. The intensities are measured by first placing distilled water free of turbidity in a cell in the light path of the spectrophotometer and the instrument is balanced at 100 percent transmission. The prepared colored solution is then placed in the light bath and the transmission noted. Instrument settings to be used are as follows: Wavelength 380 mu, blue phototube in place, slit width 0.055 mm. sensitivity 2½ turns from full clockwise, and the decimal switch at 1.0.

Procedure for Ammonia

The color to be measured is produced by the reaction of ammonia with Nessler's reagent. The intensities of colors so produced by known quantities of NH_3 are used to prepare a standard curve. The intensity of color produced by a similarly treated unknown water is compared with the standard curve to determine the quantity of NH_3 present.

The intensities are measured as under nitrates except that the instru-

ment settings are as follows: Wavelength 445 mu, blue phototube in place, slit width 0.025 mm. sensitivity 2½ turns from full clockwise, and decimal switch at 1.0. After the colors have been developed, the samples, especially the ones of lower concentration, upon prolonged standing may darken to a degree perceptible to the spectrophotometer. For this reason the intensities should be measured just 10 minutes after addition to the Nessler's reagent. Also, a check of the standard curve should be made each time new reagents are prepared.

Analysis for Phosphates

The color to be measured is produced by the reaction of phosphate with ammonium molybdate in 10N H_2SO_4 and stannous chloride. The same general plan of analysis is used as for nitrates. Instrument settings are as follows: Wavelength 700 mu, red phototube in place, slit width .025 mm. sensitivity 2½ turns from full clockwise, and decimal switch at 1.0.

Accuracy and Precision

Several workers in this field, including some noted in the bibliography, have evaluated the accuracy of the spectrophotometer in absolute terms, that is, by means of standard deviations, etc. The spectrophotometer is a relatively new instrument. It is suggested that its use replace older techniques. A more practical evaluation of the instrument might then be its direct comparison against the older proceddures. Such a comparison is more difficult to analyze but we felt it worthwhile.

Nine chemists, most of them with many years of experience, analyzed widely differing waters using slight modifications of the Association of Official Agricultural Chemists' methods. Of these waters, 34 were shipped to our laboratory and analyzed by means of the spectrophotometer. In the case of those elements using the flame attachment, the average deviations were: calcium, 9 ppm.; magnesium, 1 ppm.; sodium, 5 ppm.; potassium, 4 ppm.; and sulphate, 20 ppm.

Comparing the slopes of the calibration curves of the above metals, it is seen that the accuracy of the magnesium determination is about one-third of the other flame determinations. We adduce, since the poorest spectroscopic method gave the best comparative results, that the accuracy of the two were of the same order, and furthermore, that the accuracy of the spectrophotometer methods was greater in the case of calcium, sodium, potassium and sulphate. Comparison of the absorption colorimetry techniques showed an average deviation for ammonia of 5 ppm. and for nitrates 12 ppm.

Tests for both ions require considerable preparation before the colors are finally obtained. Care must be exercised to reduce errors in technique of color preparation in order to utilize fully the high precision inherent in the spectrophotometer.

Summary

Techniques are outlined for the use of the Beckman model DU spectrophotomter and its flame attachment for analyses for eight ions. In using the flame attachment very tedious standard techniques have been replaced by a few very simple operations. Time for analysis has been greatly decreased, the quantity of sample required greatly decreased, and the accuracy of analysis generally increased. The absorption colorimeter techniques described do not save a great deal of time but accuracy is improved.

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Composition of Certain Beet Diffusion Juices from the 1950 Campaign[1]

J. B. Stark, A. E. Goodban, and H. S. Owens[2]

Four years ago the Committee on Processing Problems for the Sugar Beet Industry recommended that determination of composition of processing liquors be undertaken because of its primary importance in the field of sugar beet technology. The committee believed that such knowledge would provide background for evaluation of present processing procedures and enable investigators to predict more precisely the possibilities of new methods for purification of beet diffusion juice.

We have published the results obtained on processing liquors for the 1949 campaign (1, 2)[3]. These results indicate that the present defecation procedure removes only certain colloids (such as pectin) along with citrate, oxalate and phosphate ions. Our attention was then focused on diffusion, because this process offers the first opportunity to achieve any purification in the factory. We have analyzed single samples of diffusion juices taken from nine factories located in all parts of the country to obtain some information on effect of locality of growth on the composition. These results from the 1950 campaign are presented here.

Materials and Methods

The samples were obtained from Manteca and Betteravia, California; Toppenish, Washington; Rupert, Idaho; Sidney, Montana; Brighton, Colorado; Centerfield, Utah; Carrollton, Michigan, and Moorhead, Minnesota. Except for the California samples, they were concentrated *in vacuo* at the factory and preserved with toluene. The two samples from the California factories were treated with toluene and transported directly to the laboratory without concentration. All juices were stored at 3° C. to inhibit microbial action. Before analysis the samples were diluted to approximately 10° Brix and filtered through a bed of filter aid.

Chloride, sulfate, phosphate, oxalate and citrate were determined by published methods on juices that had been treated with a cation exchanger.

The remaining non-amino organic acids were first separated by anion exchange fractionation. Lactic and glycolic acids were determined by ceric ion oxidation (3); malic by reaction with 2-7 dihydroxynaphthalene in sulfuric acid and measuring the color in a spectrophotometer (4); and pyrrolidone carboxylic acid (PCA) by total nitrogen analysis. In isolated cases, we determined acids by measuring areas on papergrams and comparing them with areas of known amounts of acid, using the chromatographic technique described earlier (5).

Total nitrogen, amino nitrogen, amide nitrogen and ammonia were determined on the original filtered juices by the usual procedures. Amino acids were adsorbed on a cation exchanger, then eluted with ammonia. They were then analyzed microbiologically. Betaine was analyzed by the reineckate method (6).

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[1] Report of a study made under the Research and Marketing Act of 1946.

[2] Western Regional Research Laboratory, Albany, California; Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture.

[3] Figures in parentheses refer to literature cited.

Results and Discussion

Analyses for the non-amino organic acids are given in Table 1. There is considerable variation from one sample to another except for citric acid. If we consider the known effect of fertilizer, soil composition and light conditions (7) on metabolism of plants, these variations are to be expected.

In addition, glyceric and fumaric have been tentatively identified. These two acids, succinic acid and two other unidentified acids are present in quantities less than 10 mg./liter.

Table 1.—Organic Acids in Diffusion Juice—1950 Campaign, 10% RDS

Factory	mg./liter at 10% RDS					
	Lactic	Glycolic	Malic	PCA	Oxalic	Citric
Betteravia	1,030	215	48	343	645	592
Brighton	82	23	167	104	267	473
Carrollton	775	92	96	212	221	233
Centerfield	208	88	(260)[1]	374	94	317
Manteca	288	Nil	191	182	771	531
Moorhead	1,610	26	99	425	211	621
Rupert	180	Nil	145	465	Nil	326
Sidney	585	39	112	435	200	744
Toppenish	335	175	(250)[1]	300	261	702

[1] From paper chromatograms.

Of the compounds listed in Table 1, lactic acid has the greatest interest. Two years ago we assumed that it is a normal constituent of beets. Since then we have analyzed juice pressed from beets from the Imperial valley, Alvarado and Woodland, California, and detected no lactic acid. Thus if any is present, the amount is less than 50 mg./liter (10% RDS). The lactic acid present in diffusion juice in the quantities shown in Table 1 may arise during the sampling and concentration. If not, it represents a serious loss of sugar which might be prevented with bactericides or, perhaps, by better sterilization of equipment and beet cossettes.

Table 2.—Inorganic and Total Acids in Diffuson Juice—1950 Campaign, 10% RDS

Factory	mg./liter					
	Chloride	Sulfate	Phosphate	Total Acid[1]	Total Acid Accounted for[1]	Recovery %
Betteravia	606	292	651	87.6	85.3	97
Brighton	341	262	386	47.2	45.1	96
Carrollton	223	211	436	52.4	46.0	88
Centerfield	392	300	174	49.5	40.2	81
Manteca	365	174	618	62.6	66.9	107
Moorhead	283	126	331	69.6	58.5	84
Rupert	186	147	305	44.0	30.8	70
Sidney	142	160	434	62.3	49.3	79
Toppenish	187	142	369	75.0	49.0	65

[1] meq./l.

Analyses of inorganic anions are listed in Table 2. Except for chloride ion, the results are about the same as for the juices reported earlier (1). Total accounted-for acid in the juices treated with cation exchange resin is generally about 80 percent or greater, except for juices from Rupert and Toppenish. Nitrate ion could account for a major portion of the unidentified acidic components.

Table 3.—Nitrogen and Acid Alcohol Insolubles for Diffusion Juice. 1950 Campaign at 10% RDS.

Factory	Nitrogen—mg./liter					Acid Alcohol Insolubles[1]
	Total	Amino	Amide	Ammonia	Betaine	
Betteravia	761	345	63	55	164	0.12
Brighton	362	107	26	10	109	0.43
Carrollton	461	126	26	22	157	0.24
Centerfield	461	118	24	21	175	0.24
Manteca	660	289	81	39	173	10.5
Moorhead	778	299	65	87	197	1.3
Rupert	445	100	15	35	151	0.31
Sidney	488	112	15	36	174	9.6
Toppenish	652	278	79	53	—	0.44

[1] g./liter

Table 3 shows the nitrogen analyses. The California, Washington and Minnesota juices are much higher in nitrogen than the others. The difference between total nitrogen and the sum of amino, amide and ammonia nitrogen is nearly constant, and indicates that betaine and purine bodies are not greatly influenced by the environmental growing conditions of the beets. The betaine analyses tend to confirm this assumption.

Table 4.—Amino Acids in Manteca Diffusion Juice—1950 Campaign at 10% RDS (Microbiological Assay).

	mg./liter				
Alanine	67	Isolucine	62	Proline	22
Arginine	11	Leucine	49	Serine	82
Aspartic	125	Lysine	16	Threonine	39
Glutamic	182	Phenylalanine	9	Tyrosine	37
Glycine	13	Methionine	9	Valine	45
Histidine	6				

The high values for alcohol-insoluble material for juices from Manteca and Sidney are due to the presence of dextran as proved by periodate oxidation and by hydrolysis to glucose. A period of several months had lapsed before this analysis was run and either leuconostoc or enzymes from it could have split the sucrose and synthesized dextran.

Table 5.—Amino Acids in Diffusion Juice—1950 Campaign at 10% RDS (Microbiological Assay).

Factory	mg./liter		
	Glutamic	Aspartic	Leucine
Betteravia	247	157	51
Brighton	56	48	18
Carrollton	105	76	21
Centerfield	119	94	28
Manteca	182	125	49
Moorhead	417	184	36
Rupert	44	73	22
Sidney	56	73	34
Toppenish	273	173	45

A fairly complete analysis of amino acids in Manteca diffusion juice is summarized in Table 4. Aspartic and glutamic acids are the predominant amino acids. The analyses for these two and leucine in all the diffusion juices are shown in Table 5. This table emphasizes the fact that the Rocky Mountain region and Michigan yield sugar beets low in amino acids compared to the rest of the country.

In 1951 cossettes and diffusion juices from two factories in the high-nitrogen and two in the low-nitrogen areas were analyzed. This project was undertaken to determine more exactly how much purification is accomplished by present diffusion methods. Results will be reported next year.

Summary

Analyses of sugar beet diffusion juices from nine factories are presented. Variation among most of the constituents is manifold but beet juice from the Rocky Mountain States and Michigan is low in nitrogen compared to that obtained from Minnesota and along the Pacific coast.

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Lime-Salts Determination by Direct Colorimetric Titration

ROBERT R. WEST AND ROBERT S. GADDIE[1]

The standard soap method (1)[2] for determination of total hardness of water is being largely superseded by a convenient titration method employing a color indicator. This new method is based on the titration of a water sample with an organic sequestering agent which has the ability to form soluble non-ionic chelates with calcium and magnesium. The titration is performed on a solution buffered to pH 10, utilizing an indicator which is red in the presence of calcium and magnesium ions and blue in their absence.

Chelates formed in the alkaline pH range between Versene[3] (Disodium dihydrogen ethylene diamine tetraacetate dihydrate) and calcium and magnesium are particularly stable, and in the determination of total hardness in water the Biedermann and Schwarzenbach method (1) or a modification thereof is almost universally used. Because of the simplicity and accuracy of this method, an investigation was conducted during the 1951-52 campaign with the aim of adapting this method to the determination of lime salts in factory process syrups. It was known that the Schwarzenbach method is not applicable if the solution to be tested contains more than 0.07 ppm of copper or 1 ppm. of manganese; and that in this case an inhibited indicator must be used (2). Such an indicator may be obtained from the Hach Chemical Company of Ames, Iowa.

The indicator has a deep blue color in solution at pH 10. In the presence of magnesium, however, a wine-red complex is formed. When, in the presence of a small amount of this dye, sufficient Versene has been added to chelate all of the magnesium present, a sharp color change from red to blue occurs. When calcium is also present in solution it is titrated before the end point since Versene will first chelate calcium ions. For this reason magnesium is usually deliberately introduced into the standard Versene solution.

Procedure

The Versene solution used in these tests was prepared as follows: To 7.0 gm. of reagent grade disodium dihydrogen ethylene diamine tetraacetate dihydrate dissolved in 750 ml. distilled water add 0.1785 gm. $MgCl_2.6H_2O$ and dissolve to a perfectly clear solution. This solution is standardized against a primary calcium standard containing .001 gm. CaO per ml. and adjusted before titration to a pH of not less than 5.0. The Versene solution is adjusted to exact equivalence with the standard by utilizing the following titration procedure:

To 10 ml. of the calcium standard pipetted into an Erlenmeyer flask, add distilled water to make 100 ml. and add approximately 1 gm. (measured in a plastic or stainless-steel dipper) of Uni-Ver Buffer-Indicator powder (Hach Chemical Co.) which has been finely ground in a mortar. Swirl and titrate to the discharge of the red tint; the end point is signified by the appearance of a true blue color.

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[1] Research Chemist and General Chemist Respectively, Utah-Idaho Sugar Co.
[2] Numbers in parentheses refer to literature cited.
[3] Versene is the trade name of this compound registered by the Bersworth Chemical Co., Framingham, Mass.

When applied to determinations of lime salts in factory syrups, 20 ml. of the syrup (diluted if necessary to 13-15 Brix) is pipetted into a 250-ml. Erlenmeyer flask and made up to 100 ml. with distilled water. To this solution is added the Uni-Ver (1 gm., measured by the dipper) and the titration is carried out as outlined above. In most cases the water blank will be zero; almost certainly so small that it may be ignored in interpreting the results by the use of the standard tables for CaO by soap solution in thin juices.

It would be well to point out here that the reaction is not a rapid one, and it is very important that the Versene solution be added at a moderate but fairly constant rate so that the reaction does not lag behind the additions of solution and thus cause the end point to be overshot. Once the operator understands that the final additions of titrating solution must be added slowly, little difficulty will be experienced.

Experimental Results

In the investigational work 15 Brix pure sucrose solutions as well as factory syrups were employed, known increments of calcium and/or magnesium being added previous to the titration. Comparisons were made against standard soap solution (1 ml. = .001 gm CaO) prepared by conventional procedures.

Table 1 presents a summary of 156 determinations and shows the improved accuracy which may be realized from the Versene method as compared to the soap solution method. This table represents average and maximum deviations from the known conditions found when comparing the two methods.

Table 1.

Solution	CaO Added Mg	MgO Added Mg	Versene		Soap Solution	
			Average Deviation	Maximum Deviation	Average Deviation	Maximum Deviation
Pure Sucrose	1 to 10		.01	.02	.05	.11
		1 to 6	.01	.03	.07	.13
	.8 to 8	.2 to 2	.01	.03	.07	.16
Thin Juice	1 to 10		.02	.05	.11	.19
		1 to 6	.01	.04	.09	.16
	.8 to 8	. to 2	.02	.09	.13	.31
Standard Liquor	1 to 10		.02	.06	.10	.17
		1 to 6	.03	.04	.11	.16
	.8 to 8	.2 to 2	.04	.09	.14	.29

It can be plainly seen from Table 1 that the error in determination is considerably less when using the Versene than when using soap solution; however, an even greater difference would be noted if variations experienced by different operators running duplicate determinations were tabulated. It is quite generally established that the soap solution method introduces a great deal of variation from one operator to another, primarily in the matter of just exactly what distinguishes the end point.

Table 2.—Variation in Quadruplicate Analyses.

Solution	Versene		Soap Solution	
	Average Deviation	Maximum Deviation	Average Deviation	Maximum Deviation
Pure Sucrose	.01 ml	.03 ml	.03 ml	.09 ml
Thin Juice	.02	.05	.06	.12
Standard Liquor	.03	.05	.07	.16

Table 2 illustrates the reproduceability encountered under average operating conditions by the same operator. Two different known amounts of calcium and magnesium were added to each solution for the titrations shown.

Table 3 shows the reproduceability obtained when duplicate analyses were made by several operators in different laboratories.

In the Versene method in these experiments, it was found possible to obtain duplication of results within an accuracy of .05 to .1 ml. over a titration range of 0-10 ml. This represents an accuracy of about .002 to .004 percent lime salts on 100 Brix over a range of 0-.350 percent lime salts on 100 Brix for average syrups. A few practice determinations by even an inexperienced operator should enable him to recognize the end point so that a reproduceability of about .1 ml. for routine analyses should be obtainable in the factory laboratory. That this is possible has been well substantiated during the past campaign, as little difficulty was encountered in training operators to run the analyses.

Table 3.—Lime Salts Found in Factory Syrups—CaO on 100 Brix.

Sample		General Laboratory Results		Factory Results
		Versenate	Soap Solution	Versenate
Thin Juice	No. 1	.068	.081	.066
	2	.074	.090	.074
	3	.070	.079	.066
	4	.112	.130	.109
	5	.088	.101	.090
Standard Liquor	No. 1	.048	.061	.048
	2	.052	.059	.050
	3	.072	.091	.071
	4	.080	.097	.080
	5	.063	.071	.062

Interfering ions were investigated as shown in Table 4. Tests were run on 15 Brix pure sucrose solutions containing .2 mg. CaO plus .05 mg. MgO per ml. In all cases where the addition of the ion in question caused a great deviation from neutrality, adjustment was made to near neutrality in order that the buffer mixture might function correctly. In some cases the interfering ion altered the typical red-to-blue color change at the end point. However, accuracy of end point determination at the maximum color change was unaffected. Table 4 lists only that concentration above which the error may exceed an arbitrary maximum of 0.1 ml. in a 5.0 ml. titration.

Observations

Up to a lime salts concentration of about .160 percent CaO on 100 Brix it was found possible to obtain a one-drop end point with the Versene, using a 10 ml. Koch automatic burette with a micro-tip delivering 42 drops per ml. Beyond this concentration, and in certain dark-colored syrups, it was necessary to exercise considerable care in the recognition of the end point, but in all cases it could be determined within a range which would correspond to 1-2 drops from a conventional burette. Such a small variation introduces only an inconsequential error in the actual lime salts value.

As the very nature of the soap solution determination made the use of such equipment impractical, a standard burette delivering 22 drops per ml. was used in the soap determinations. As in the case of the Versene, 1 or 2 drop end points could be realized on solutions containing very low lime salts concentrations, but in most cases the end point was quite indistinct, often requiring the addition of 3-5 drops of soap solution beyond the first false end point indication to obtain a final value. This represents a far greater possible error than in the case of the Versene, and in all cases required considerably more time per analysis.

Table 4.—Tolerance Levels for Interfering Ions.

Ion	ppm in Syrup
Cu^{++}	100
Fe^{+++}	100
Fe^{++}	100
SO_3^{--}	1000
PO_4	1000
NO_3^-	1000
CO_3^{--}	1000
Cl^-	10000
SO_4^{--}	10000
Sucrose	500000

Conclusions

The Versene method of lime salts determination on factory syrups offers several advantages over the conventional soap solution method, foremost being greater speed, greater accuracy, and greater reproduceability. It enables different operators to produce highly consistent and comparable results, and gives better indication of true lime salts concentration. In no respect did the Versene method prove to be inferior to the soap method; rather, it was in every case tested equal to or superior to the soap method.

Therefore, it is believed that this method is fully worthy of inclusion into the methods of factory syrup analyses.

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A Simple Method for the Determination of Clostridium Thermosaccharolyticum in Sugar

A. Wendell Holmes and Paul S. Nicholes[1]

The micro-organisms which are of most concern in the spoilage of non-acid pack canned foods are the thermophilic spore-bearing bacteria (1)[2]. Sugar was first suspected as a source of contamination by these organisms as early as 1926, and, as sugar is an essential ingredient in practically all canned foods, the National Canners' Association has established standards for its bacterial purity (2). To control the production of sugar to meet these specifications, the analysis of a large number of samples is necessary. It was the purpose of this investigation to devise a less cumbersome, and therefore a more efficient method, for the detection of a certain specific thermophilic anaerobes which may contaminate sugar.

Three major groups of bacteria have been shown to be most troublesome to canners: (a) the stearothermophilus of Donk (3), a facultative aerobic sporebearing thermophile which causes "flat sour" spoilage; (b) *Clostridium nigrificans* (4), an anaerobic organism which produces hydrogen sulfide and gives rise to "sulphur stinker" spoilage; and (c) *Clostridium thermosaccharolyticum* (5), an obligate anaerobe which produces gas, mainly carbon dioxide and hydrogen, but does not produce hydrogen sulfide, and causes spoilage known as "hard swells." It is this last group with which this study is concerned.

McClung (6) conducted extensive investigations of the physiological and cultural characteristics of the thermophilic anaerobes found in sugar, and suggested the name by which they are now known, *Clostridium thermosaccharolyticum*. He found them to be fastidious in their requirements, particularly with respect to anaerobiasis. Cameron, Williams and Thompson (7) conducted a study of the causes of spoilage in canned foods and devised methods for culturing these anaerobes routinely. Their medium was a liver infusion broth sterilized over bits of liver tissue and sealed for anaerobiases with a layer of nutrient agar. The medium was found to be well suited to the detection of these organisms, and is the medium recommended by the National Canners' Association. For routine analysis of sugar, the method is cumbersome and slow, and requires several lengthy operations to prepare the medium and to complete the test.

Several methods for the aerobic culture of anaerobes have been devised. Trenkmann (8) was the first to suggest that anaerobes would be cultured under aerobic conditions by reducing the oxygen tension with an alkaline sulphide. Quastel and Stevenson (9) were able to grow *Cl. sporogenes* in the presence of a small amount of a compound containing a sulfhydryl group. Brewer (10) showed that the addition of a small amount of agar combined with a reducing agent was of great value in the culturing of anaerobes. He showed also that agar in the amount of 0.05 percent together with a reducing compound such as sodium thioglycollate initiated growth of anaerobes. Marshall, Gunnison and Luxen (11) have also shown that a medium containing a substance similar to the medium of Brewer was satisfactory for the cultivation of anaerobes under aerobic conditions.

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[1] Chief Bacteriologist, Utah-Idaho Sugar Company, and member Department of Bacteriology, University of Utah, College of Medicine, respectively.

[2] Numbers in parentheses refer to literature cited.

A study of the literature has shown no evidence that an aerobic medium has been utilized for the growth of *Cl. thermosaccharolyticum,* nor has an attempt been made to utilize such a medium in the routine analysis of sugar samples for specification purposes. This investigation was conducted in an attempt to test various media for suitability as a routine testing medium to replace the cumbersome method now recognized by the National Canners' Association.

Methods and Materials

Sugar samples known to be contaminated with *Cl. thermosaccharolyticum* were secured from two refineries which sporadically produced contaminated sugar. In addition, three samples of sugar were obtained from the National Canners' Association.

In order that the experiments be well controlled, all media tested were compared with the routine medium recommended by the National Canners' Association (2) and prepared according to the specifications outlined in the A.O.A.C. page 754, paragraph 40.14 (b). The standard procedure of the A.O.A.C. for the detection of *Cl. thermosaccharolyticum* was used in all tests, to wit:

> Twenty grams of sample sugar were placed in a sterile 250-ml. Erlenmeyer flask. Sterile water was added to a total volume of 100 mls. The sugar-water solution was then brought to boiling and allowed to boil for five minutes. Any loss by evaporation was replaced with sterile distilled water. Twenty mls. of the boiled solution were dispensed equally among six tubes each of the test media, and of the control medium. The liver extract broth tubes were overlaid with a sealing agar; the media of low oxygen tension were placed directly into the incubator after seeding. All tubes were incubated at 55° C. for 72 hours and then observed for the production of gas and other criteria distinctive for positive tests.

Results

Several media of low oxygen tension were investigated to meet the requirements of sugar analysis. These media were prepared using commercially dehydrated liver, liver fractions and combinations of these substances with enrichments of tryptone, peptone, dextrose, etc., both with an agar seal and at a reduced oxygen tension by the addition of thioglycollic acid. Only negative to weakly positive results were obtained.

The medium of Cameron, et al (7) was modified by using thioglycollic acid as a reducing agent instead of an agar seal. This also gave sporadic and unreliable results. The medium which finally proved to be the most satisfactory was the commercial preparation "Fluid Thioglycollate, Difco." This broth is prepared by adding 29.5 grams of the dry ingredient to 1 liter of distilled water, boiling for a few minutes to dissolve, and tubing in 150 mm. x 18 mm. tubes. Each tube of medium contained a 75 mm. x 10 mm. gas tube. The medium was autoclaved in the tubes at 121° C. for 20 minutes at 15 lbs. pressure. All data pertaining to the dehydrated product may be obtained from the Difco manual, eighth, edition. The final pH of the broth is 7.1.

The results obtained comparing the standard medium with the thioglycollate method are shown in Table 1.

A composite sample was made of several of the sugar samples listed in Table 1 to obtain a larger homogeneous mixture for an investigation of

Table 1.—Results Obtained from Comparative Tests of Liver Extract Broth and Thioglycolate Broth in 6 Tube Tests.

Sample Number	Liver Broth	Thioglycollate Broth	Sample Number	Liver Broth	Thioglycollate Broth
Utah 1	++++--	++++++	Utah 13	++++++	++++++
Utah 2	++++++	++++++	Utah 14	++++++	++++++
Utah 3	++----	++++--	Oregon 1	++++++	++++--
Utah 4	++++--	++++++	Oregon 2	+-----	+++---
Utah 5	++++--	++++++	Oregon 3	+-----	++----
Utah 6	------	++----	Oregon 4	++++++	++++++
Utah 7	++++++	++++++	Oregon 5	------	++----
Utah 8	++++++	+++++-	Oregon 6	+-----	------
Utah 9	++++++	+++++-	NCA 7087	++----	------
Utah 10	+++---	++++++	NCA 7021	++++--	+++++-
Utah 11	++++++	++----	NCA 1949	++++--	+++++-
Utah 12	++++++	+++++-			

the comparative sensitivity of the media. To maintain a constant composition of the innoculum a dilution of this composite sample was made using as a diluent a sugar known to be free of thermophilic anaerobes; thus, the total weight of each sample amounted to 20 grams to make the sample comparable to the standard procedure. The procedure was otherwise as outlined for the standard in a previous paragraph. It may be observed from Table 2 that the thioglycollate medium is equally as sensitive as the liver extract broth.

Table 2.—Results of Tests Showing Comparative Sensitivity of Liver Extract Broth and Thioglycolate Broth in Single Tube Tests.

Dilution	Liver Broth	Thioglycollate Broth
1:5	+	+
1:7.5	+	+
1:10	+	+
1:15	+	+
1:20	+	+
1:30	+	+
1:40	-	+
1:60	-	-
1:80	-	-

Table 3 presents the results of tests made using National Canners' Association reference culture T.A. 3814. This culture was diluted with sterile water to the dilutions shown in the table, and 1 ml. of each dilution was seeded into a tube containing sugar equivalent to a standard test. Here again, it was observed that while the two media at a dilution of 1:80 were only weakly positive, each showed equal amounts of turbidity and gas production.

Throughout the investigation it was noted that best results were obtained when the liver extract broth and the thioglycollate medium were seeded as soon as possible after removal from the autoclave, and while the innoculum was still near the boiling point. Results were more consistent if the fluid thioglycollate was made fresh at least every other day. It is the practice in our laboratories to heat both media under pressure 5 to 10 minutes before seeding with the sugar solution.

Conclusions

It is evident that the liquid thioglycollate medium, Difco, is equally as sensitive for the detection of thermophilic anaerobes as the liver infusion medium which is used at present as standard procedure by the National Canners' Association. This being the case the thioglycollate medium has much to recommend its use as standard procedure. The preparation of the medium is much simpler, and if the Difco product is utilized a much more standard preparation is obtained than could be had in the preparation of the liver medium in the laboratory.

Table 3.—Results Using NCA Reference Culture T.A. 3814 in Two Tubes Tests.

Dilution	Liver B Broth	Thioglycollate Broth
1:5	++	++
1:10	++	++
1:20	++	++
1:40	++	++
1:80	+–	+–
1:160	+–	+–

The Utah Idaho Sugar Company has adopted the thioglycollate method for the routine detection of thermophilic anaerobes, and is justified by the standards it maintains in the control of its sugar. As a routine procedure in the laboratory, any sample showing one tube positive for thermophilic anaerobes rejects that lot of sugar for canners' specification.

The method is recommended to the National Canners' Association as an alternate method for its standard procedure for the detection of thermophilic anaerobes.

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A Study of Siloed Beet Pulp

JAMES H. TURNER, JOHN NIGRO, AND ROBERT H. COTTON[1]

The objectives of the study were threefold: first, to determine what percentage of solids entering the pulp silo at Swink is lost; second, to determine what compounds of economic significance are present in silage drainage liquor, or effluent, from pit; and, finally, to assess some of the stream pollution factors in open pit silo storage of pulp. The work was done on pulp from the 1949 campaign at Swink.

Material Losses in the Pulp

Briefly, an accounting was made of pulp introduced to the silo versus pulp removed, each expressed on a dry basis. Thus one could estimate the solid material lost in storage. Pulp introduced was calculated from the total beet slice and the average marc content (4.5 percent) for the Rocky Mountain area. A record was kept of pulp removal at regular intervals and solids content was determined at the same time. Data are presented in Table 1. The results are in agreement with those of Coke and Jones (1)[2].

Table 1.—Solids Lost in Pulp Silo.

Original amount (in tons) Pulp Solids Introduced (=71578 x 0.045)		3,220
Total Accounted for (removal plus residue)		1,715.7
Tons Pulp Solids Removed	1,683.60	
Tons Pulp Solid in Pit (6/26/50)	32.1	
	1,715.7	
Tons Pulp Solids Lost		1,504.3
Percentage Loss in Pulp Solids $\left(= \frac{1504.3 \times 100}{3220}\right)$		46.7%

A loss of 46.7 percent of the solids was experienced in the 1949-50 season at Swink. Since by-product utilization may well be a matter of life and death to this industry such a loss is of paramount importance.

Table 2 shows marketable pulp obtained from the silo on a wet basis. It agrees well with the conventional figure of 27.5 percent of beets sliced.

Table 2.—Marketable Pulp from Swink Silo, 1949 Campaign (Wet Basis).

Tons of Pulp Out of Pits:	
10/14/49—1/31/50	7,769
February	3,069
March	3,190
April	2,941
5/1/50—6/26/50	2,500
Estimated residue	300
	19,769

$$\frac{19{,}769}{71{,}578} \times 100 = 27.55\% \text{ pulp recovered on beets}$$

Figure 1 shows moisture content of siloed pulp throughout the season. Note the progressive increase in solid content; thus in May a ton of pulp has 100 percent more solids than does a ton in October. This curve is very helpful to us in cattle feeding studies when we want to calculate total digestible nutrients, etc.

Analysis of Silage Drainage Liquor, or Effluent

Periodic anayses of the water draining from the pulp were made from October 22, 1949, to June 28, 1950, Table 3.

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[2] Numbers in parentheses refer to literature cited.

Table 3.—Effluent Analyses.

Sample No.	Date Rec'd.	Volume of Wet Pulp (% Sample)	Estimated Solids by Brix 20° C.	Specific Gravity d 20°/4°	pH	Free Acid (c) (Equiv./liter)	Galacturonic Acid %	Total Uronides %
1	10/22/49	4	0.65°	(1.0003)[1]	4.51	0.00571	0.037	0.056
2	11/2/49	4	0.50°	1.0001	4.30	0.01382	0.024	0.0716
3	11/9/49	3	0.38°	0.9998	4.30	0.00723	0.0104	0.0276
4	11/18/49	6	0.52°	(0.9999)[1]	4.28	0.00840	.....	.....
5	11/24/49	3.5	1.53°	1.0036	4.09	0.1037	0.1011	0.3120
6	11/30/49	8	1.94°	1.0054	4.02	0.1168	0.1388	.....
7	12/7/49	6	1.83°	1.0048	4.00	0.1177	0.1458	0.4204
8	12/13/49	< 0.5	1.50°	1.0037	4.12	0.1024	0.0687	.....
9	12/20/49	1	1.43°	1.0034	4.10	0.1164	0.0551	0.2145
10	12/28/49	6	1.93°	1.0055	4.00	0.1623	.....	.....
11	1/4/50	< 0.5	1.54°	1.0037	4.09	0.1339	0.0492	0.2666
12	1/10/50	1.5	1.75°	1.0046	4.10	0.1562	.....	.....
13	1/17/50	1.5	2.00°	1.0057	4.02	0.1768	0.1382	0.4075
14	1/24/50	0.5	1.65°	1.0042	4.18	0.1330	.....	.....
15	1/31/50	6.5	2.00°	(1.0056)[1]	4.08	0.1688	0.0979	0.3977
16	2/8/50	35	2.13°	(1.0061)[1]	4.10	0.1516	.....	.....
17	2/14/50	< 0.3	0.95°	(1.0015)[1]	4.51	0.0538	0.0194	0.0839
18	3/1/50	< 0.1	0.76°	(1.0008)[1]	4.73	0.02452	.....	.....
19	3/15/50	1	0.75°	(1.0007)[1]	4.62	0.02885	0.0265	0.0222
20	3/29/50	< 0.3	0.72°	(1.0006)[1]	4.86	0.01669	.....	.....
21	4/12/50	< 0.1	0.66°	(1.0004)[1]	4.82	0.02229	0.00921	0.0159
22	4/28/50	< 0.5	0.81°	(1.0010)[1]	4.62	0.03581	.....	.....
23	5/12/50	10.5 (19)[2]	1.75°	(1.0046)[1]	4.00	0.1851	0.0777	0.2499
24	6/1/50	0.5	1.50°	(1.0037)[1]	4.13	0.1459	.....	.....
25	6/14/50	0.5	1.42°	(1.0034)[1]	4.18	0.1380	0.0810	0.2004
26	6/28/50	6.5	1.70°	(1.0044)[1]	4.06	0.1752	.....	.....

[1] Indicates value secured by subtracting 0.0004 from density corresponding to Brix reading; this relationship existed for a set of twelve determinations and it was not considered worthwhile to repeat separate specific gravity determinations thereafter.
[2] Value secured by measured heights of solid and liquid in original bottle.
[3] Measurements of volatile acid (discontinued after first three determinations) were about 85% of free acid.

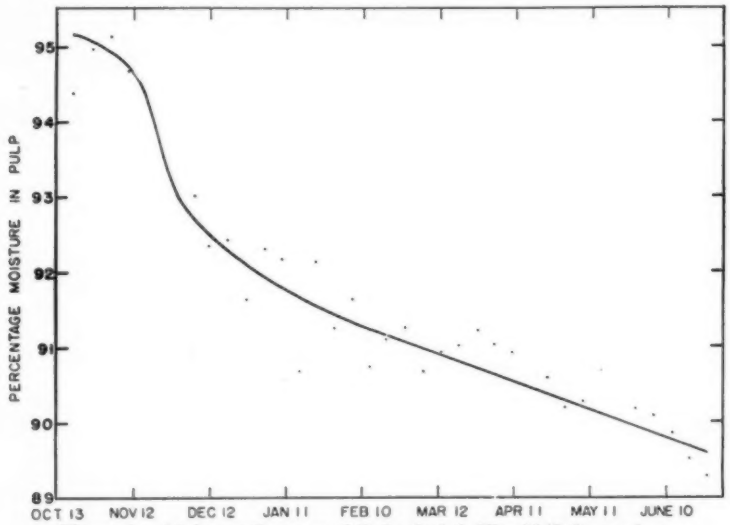

Figure 1.—Moisture Content of Pulp, Swink Silo, 1949 Campaign.

Column 3 in Table 3 shows the volume of loose pulp particles found in the drainage liquor. The average for the campaign was 4.5 percent, a significant loss in revenue. Unfortunately the absolute volume of the effluent and, therefore, of the solids lost in effluent is not known. A device installed to measure this was crushed by pressure of the pulp against it. A screen to recover this pulp might be worth further study.

The Brix values in column 4 are a rough picture of the soluble materials lost in drainage. They are primarily organic matter (Bureau of Standards (2) shows ash value of only 0.19 percent on comparable material) much of which is organic acid (see columns 6, 7 and 8). Pulp contains pectin which is broken down to galacturonic acid. The last column includes galacturonic acid and pectin in various states of decomposition. Galacturonic acid is not a normal article of commerce today, but if it could be recovered cheaply it would be a good starting point in Vitamin C synthesis. Other uses no doubt could be developed. There are other acids present in the effluent, as shown in Table 4.

Table 4.—Volatile Acids in Composite Effluent Samples 5 to 11 (Nov. 24 to Jan. 4)

Formic Acid	0.2114 gms./liter	0.02%
Acetic Acid	4.66 gms./liter	0.47%
Butyric Acid	3.28 gms./liter	0.33%
Lactic Acid	0.0903 gms./liter	0.009%

The sales prices of the four acids are, respectively, 16, 9, 35, and 27 cents per pound. Can they be recovered economically? We have studied their recovery by ion-exchange and distillation. So far we have failed to develop an economic process, in part because of the extreme dilution. However, if a market develops for galacturonic acid a combined recovery of the five acids may some day be feasible.

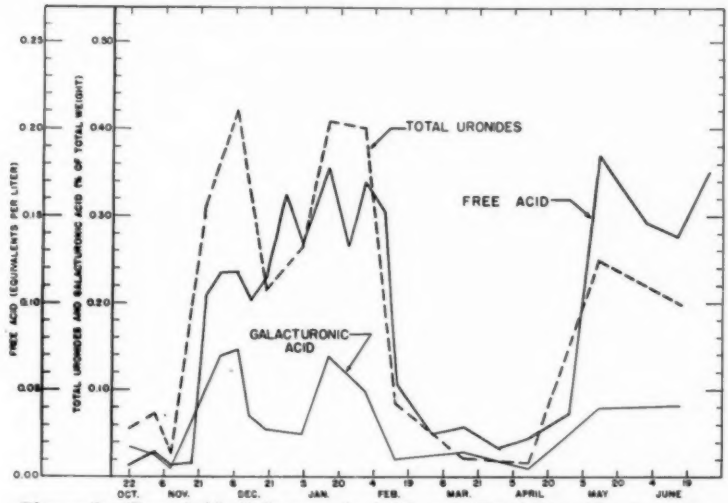

Figure 2.—Free Acid, Galacturonic Acid, and Total Uronides in Pulp Effluent, October, 1949, and June, 1950.

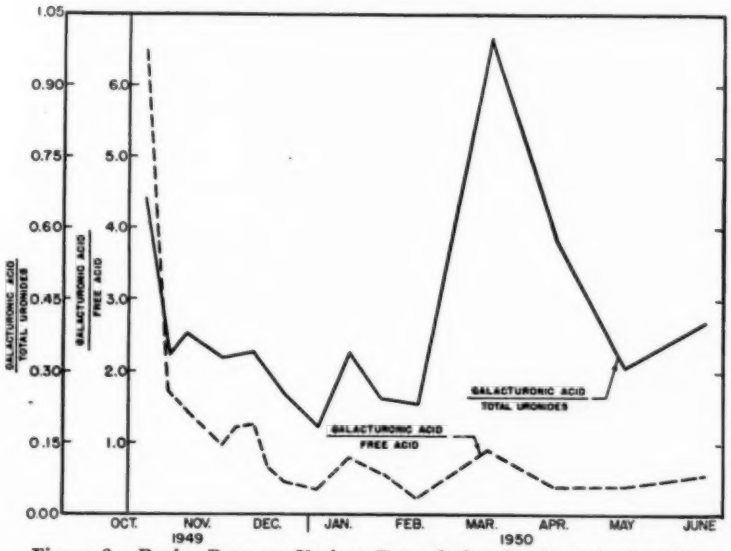

Figure 3.—Ratios Between Various Degradation Products in the Silo as a Function of Time.

The Sugar Research Foundation (3) (4) has made considerable progress in obtaining both pectin and galacturonic acid from pulp. Perhaps some

day this will lead to new sources of revenue to our industry. Therefore, we feel that it may be of interest to show changes in these components with the season (figures 2 and 3). The changes in free acids, galacturonic acid and total uronides were remarkably parallel. Uronides are converted to galacturonic acid by an enzyme produced by bacteria feeding on the pulp (such as Penicillium ehrlichii).

Probably several enzymes are involved (5) and, furthermore, once the pulp mass becomes acid the degradation reactions are accelerated by the catalytic activity of the acid itself. Data in figures 2 and 3 give valuable clues to further research since during certain periods conditions were vastly more favorable for galacturonic acid production that at other times.

Figure 3 shows that at about March first all uronic substances (pectin materials) in the drainage liquor were present as galacturonic acid—a very favorable situation if one were to commercially produce galacturonic acid provided a good effluent flow could be obtained as in January and June. When and if a good market develops for galacturonic acid at an attractive price this work will be a basis for further intensive research.

Appreciable quantities of arabans have been found in the effluent but no ready use for these has been developed.

Silo Effluent in Stream Pollution

Since cattle thrive on wet pulp our drainage water is not toxic. Since it carries organic matter which will undergo further oxidation in the stream it can be said to pollute streams. This is because such oxidation will deprive fish of oxygen they need for life. Certainly streams can and do take organic matter and oxidize it without loss of fish life. It is the weight of the load in unit time that is the deciding factor. As towns grow and industries develop the discharge of organic matter into streams becomes progressively more serious. Recent legislation is making this into a more and more acute problem. A sewage disposal system capable of handling this effluent would be prohibitively expensive. Therefore, pulp driers are an attractive alternative to the pit silo since they remove this phase of the problem almost entirely.

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The Manufacture of Liquid Sugar from Granulated

A. P. ANDERSON[1]

In the last few years there has been an increasing demand for liquid sugar in Detroit and the adjacent territory. This demand has been met by eastern refiners who ship it in from New York to Detroit by barge during the open season for navigation on the Great Lakes and by tank cars during the closed season. They maintain large storage facilities in Detroit and supply their customers by tank trucks loaded from these storage tanks.

In order to protect our distribution and to be in a competitive position to supply customers who wish to convert from granulated, our management decided to install factilities for making liquid sugar from granulated.

Plans were drawn up early in the spring of 1950 for a plant to have an estimated capacity of 10,000 gallons for an eight-hour day to be installed at the Caro factory. Caro was chosen because of its large warehouse capacity, fairly central location to possible customers and because, due to several changes which had been made in the sugar end, there was enough vacant space in the factory building to install the necessary equipment. Delivery of materials was slow, but we were able to make the first delivery the last of June when the demand was beginning to reach the seasonal peak. The equipment consists of:

2—Melter tanks, 2,000 gallons capacity each, with cover.
2—Vallez filters 5 feet long 2 feet diameter 65 sq. ft. filtering surface each. We had these on hand at another plant.
1—Inversion tank, 2,500 gallons capacity. This tank is enclosed with a manhole on top through which acid and soda ash are added. It has a steam jacket on the bottom.
1—Graham vacuum cooler. This is for cooling the syrup before storage to lessen the amount of condensate in the storage tanks.
1—Small tank for mixing filter aid.
1—Small two-compartment tank with cover for receiving syrup and sweet water from the filters.
2—Storage tanks of 10,000 gallons capacity each for syrup storage. Another 5,000-gallon storage tank was put in later for invert syrup storage.
3—Gould centrifugal pumps, 25 gallons per minute and 1,750 R.P.M.

The melter tanks, pre-coat tank and receiving tanks are coated inside with Tropelite, the inversion and storage tanks with Heresite. This is a baked on synthetic resin finish. The cooler tank is made of stainless steel, the condenser of cast iron and the vapor line is made of spiral welded pipe. The melter tanks, pre-coat and inversion tanks are equipped with "Lightnin" mixers. The melter tanks also have steam coils for heating. All piping is 2 inch and 3 inch copper. The liquid sugar equipment is entirely enclosed from the rest of the factory.

The storage tanks are equipped with two Sterilamps to prevent surface bacteria and mold growth, and a blower to exhaust condensate. The air inlet is covered with a glass wool air filter, the same type as used on the

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sugar granulator. For further protection, it is covered with three thicknesses of Johnson & Johnson dairy filter cloth. These tanks are on the third floor, and the trucks are loaded by gravity flow.

The city water, which is used to melt the sugar, is high in hardness and iron content. To remove these, a softener containing a synthetic ion exchange resin called "Nalcite" is used. For heating the water, a Graham Heliflow heat exchanger is used; this produces hot water almost instantaneously.

During campaign, the amount of sugar estimated to be necessary to fill the demand for the year for Baker's Special, powdered and liquid sugar is put up in one hundred pound, plain cotton bags. This is brought out of the warehouse in the intercampaign period, as required, and the bags emptied into a hopper. A conveyor takes it from the hopper upstairs to a 66-mesh Tuftex Roball screen. The fines are sacked as Bakers' Special and the coarse goes to a bin where it is drawn off as required for powdering or to be made into liquid. During campaign, sugar for liquid is taken directly from the dry sugar bin and the amount of this sugar, as calculated from the analysis and weight of the liquid made, is added to the production for that day.

When this process was under consideration, the question of building silos for bulk storage was investigated, but the figures arrived at showed that it would be cheaper to use the method adopted than erect the silos. The cotton bags can be used over again for several years. Our figures show an average life of four years.

Two types of sugar are made, a No. 1 liquid sucrose and a No. 1 invert. The sucrose syrup has a brix of 67° and is practically water white; the brix of the invert syrup is 77°, and it has 55 percent invert sugar based on solid content. The color is light straw. Several inquiries have been made for syrups with different degrees of inversion, but so far none have been made.

When sucrose syrup is made, the granulated is dissolved in the melters with hot water and made up to 64° brix. The temperature is maintained between 80° and 85° C. The filter is pre-coated with Standard Super-Cel mixed in the pre-coat tank with some of the syrup from the melter and recirculated back to this tank until the filtrate is perfectly clear; then the syrup in the melter is cut in. Some Hy-flo is added to the melter as it goes out.

From the filter, it goes to the cooler and then to storage. The cooler brings the temperature down to about 40° C. and the brix up to 67.

When making invert, the brix at the melter is made to 72° and the syrup goes first to the inversion tank. The pH of the syrup is brought to 2.5 with C.P. hydrochloric acid and held there for about one-half to three-fourths of an hour with the temperature about 75°. Too high a temperature will, of course, cause darkening. When the inversion has reached the desired point, soda ash is added to bring the pH to 6.0, stopping the inversion. About 2 to 3 liters of acid are used and 3 to 4 pounds of soda ash. After the inversion, the invert syrup follows the same path as the sucrose syrup, filtration, cooling and storage.

To control the inversion, tests are made to determine when the desired point is reached. Nineteen ml. of syrup are taken, made up to 100 and polarized. The brix minus this polarization divided by 1.36, the specific gravity, gives the approximate amount of invert sugar present. The invert sugar is determined again by the Lane-Eynon method on all shipments.

As the plant is operated only nine hours a day and usually five days a week, it is necessary to sweeten off the filters every night. The sweet water is used in the melter the next day.

Tank trailers were adopted as the best method of delivery because of faster and more flexible delivery and because all our customers are within a radius of 100 miles. The management initially considered purchasing, operating and maintaining the trucks, but after a study calculated that it was more economical to have the delivery made by a contract carrier. He bought three tank trailers made according to our specifications and had them painted in the company's standard colors and name.

These tanks are 3,300-gallon units, lined with Heresite and equipped with a motor-driven pump. The pumps are Yale rotary piston, positive displacement type, 90 gallons per minute and run at 615 R.P.M. They have 2½ inch connections and are driven by a 220-volt V-belt motor. The tanks have five baffles which make driving easier, as they prevent the surging of the syrup when hauling a short load as is sometimes necessary because of weight restrictions in the spring and on second and third class highways. However, these baffles have made cleaning more difficult.

The trucks have no meters and the customer is billed for the weight of syrup actually delivered, calculated from the weight of the truck full and when emptied. The gas tank is also filled for each weighing, and all mud and dirt picked up on the trip is cleaned off. Our laboratory reports brix, weight per gallon, number of gallons, weight of solids, and on invert syrup, the percent invert sugar, to the customers on each load delivered.

Since dairying is one of the largest agricultural industries in Michigan, the bulk of our business has been to supply liquid sugar to manufacturers of milk products. The growth of fruit packing has not matched in volume that of the Pacific coast states. There, a few packers with a large volume take care of most of the fruit, while in Michigan we have smaller plants and their volume has not as yet justified their conversion to liquid sugar.

The dairy industry requires a sucrose syrup for making ice-cream mix and for sweetened, condensed milk, and we also have customers in the baking business for this syrup. Invert syrup is sold to bottlers and manufacturers of jams, jellies, preserves and pickles.

Producers of sweetened, condensed milk demand a sterile syrup, and for this reason it has been necessary for us to take every precaution to keep our plant and tank trucks clean and sanitary. In the melters and where the syrup is hot, we have found no signs of bacterial growth, but in the coolers, storage tanks aand trucks where the syrup is cool at times we have found the presence of a variety of Torula. This is a wild yeast which is tolerant to heavy concentrations of sugar and forms a pink colony. It does not ferment sucrose or lactose and would do no great harm in the finished product

if it should escape the pasteurizing process. The concentration of the syrup and the use of Sterilamps as well as ordinary cleaning and sanitation have prevented the presence of other yeasts, bacteria and molds, but for the elimination of Torula, extra precautions are necessary.

A regular cleaning and sanitation routine has been adopted which has been successful so far. The cooler is washed out and steamed after each day's run, and hot water is pumped through all pipe lines possible. The other lines, such as the ones to the storage tanks, are steamed. The two sucrose storage tanks are used alternately, and one is taken out of service each week, emptied and hosed out with hot water containing a detergent, steamed and then fogged with a chlorine solution. The trucks, before loading, are washed out, a man getting inside with a hose and going into each compartment, then the trucks are steamed and fogged with a hypochlorite solution. This is then pumped out to clean and sterilize the pump and hose connections.

Although the manufacture of liquid sugar is a relatively new thing in the Midwest, there is every indication as time goes on that it will prove more profitable for the sugar industry. In addition, it provides beet refiners with another product which places them in a position to compete effectively with cane sugar producers of liquid sugar.

By being prepared to offer this product to consumers who want to take advantage of the savings possible by using liquid sugar, beet sugar manufacturers are able to keep their market in areas of greater freight earnings as well as more efficiently meeting customers' demands.

Exchange of Factory Operating Data

P. W. Alston[1]

Exchange of operating data has been practiced for many years in the sugar industry. In the raw cane sugar industry the practice has been enlarged to the extent of circulating weekly and monthly reports among the factories cooperating.

A few years ago I. S. J. published a tabulation "Average Manufacturing Results from Natal, Mauritius, Trinidad, British Guiana, Hawaii, Queensland, Puerto Rico and India." A few copies of this tabulation are circulated.

For several years the data for the California beet sugar factories have been tabulated into two reports: Straight and Steffens houses. Copies of these are distributed.

In the present form this report is rather bulky and should be condensed. I would like to suggest that each one interested in the exchange take his copy home and study the arrangement with the idea of eliminating those items which are not of particular interest. Return the report within a reasonable time with recommended omissions or additions. Also include suggestions on format.

The Spreckels office has been collecting, tabulating, mimeographing and distributing these comparative reports for the California factories for several years and can continue this practice. It is suggested that in other geographical areas these data should be compiled and circulated. The practice is to send to each company sufficient copies for distribution to each factory participating.

In connection with the exchange of factory operating data some steps should be started toward exchange of analytical methods with the objective of having some uniformity in reporting.

Before the war the California operating personnel was loosely organized into a California Sugar Technologists' Association which met annually. One of the accomplishments was a compilation of the methods of analysis used by the four companies. This is out of print and also about out of date and should be reviewed on a larger scale.

Uniform methods of analysis are particularly desirable where data are freely exchanged.

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Determination of Sucrose in Sugar Beets

P. W. Alston[1]

Accurate, reproducible methods are recognized as essential tools of the chemist, and if we add the adjective "rapid" to these qualifications we satisfy the needs of the sugar chemist both for factory control and for accounting of beets purchased from the grower.

In the accounting for yields and losses in the factory our present methods are fairly reliable and satisfactory. But in those sections of the country where beets are paid for on individual sampling and analysis of the grower's delivery there is always room for questioning the laboratory results.

In the first place, we have the difficulty in obtaining a representative sample. Present practice in most California plants is to sample every truck load delivered. These samples usually weigh about 25 pounds from an average of five to six tons per load. Both tare and percent sugar are determined.

The California factories use 179.1 ml. of a seven Brix lead solution. This volume was determined and recommended by the late Dr. Bachler of American Crystal. Recently this volume has been questioned. The basis for questioning the volume was work done on determination of dry marc. The use of the dry marc determination carries all the classical objections raised in discussion of all volumetric methods where the pulp is a portion of the volume.

A few years ago Lewon and Hartmann tried a method using an extraction with 50 ml. of 5° Brix lead acetate solution.

> A normal weight of finely chopped beets is digested for 15 minutes with 50 ml. of 5° Bx lead acetate, 1 ml. of concentrated NH_4OH is added and marc precipitate and solution are then transferred to a paper extraction thimble, which is lowered into a Soxhlett extraction tube, beneath which is connected a 200-ml. volumetric flask.
>
> The apparatus used is the regular Soxhlett extraction apparatus. The washings from the digestion beaker serve as extraction liquid. The tube is connected to a reflux condenser with vacuum connection, and the flask immersed in boiling H_2O. The pressure within the apparatus is then reduced to 25 cm. Hg. absolute, so that the extraction is carried on at a temperature of about 72° C. At this temperature, 10 to 12 extractions (requiring about 1 hour in all) are sufficient to free the contents of the thimble from sugar as determined by the alphanaphthol test. The resulting extract is cooled, made up to 200 ml. and polarized.
>
> Except for a slight haziness which must be filtered off before polarizing, no lead precipitate is included in the extract. The small amount of ammonia added maintains the beet pulp at a pH of about 9 during extraction, thereby insuring against inversion. The extract itself is at a pH of less than 8 when extraction is completed so that the polarization is not affected. A single small drop of a suitable oil prevents foaming in the volumetric flask. This is proven by blank tests to have no effect on the polarization. Two samples of the same pulp were extracted simultaneously.

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[1] General Chemist, Spreckels Sugar Company.

At the same time weigh out a group of samples of the same pulp, and add to these a series of different lead additions, e.g. 175, 177, 178, 179, 181 ml. of Bx, lead acetate solution. Digest these for 0.5 hour @ 80° C, filter and polarize. By plotting a smooth curve for each set, the polarization by the digestion method equal to that by the extraction method, and hence the correct Sachs-le Docte volume, is determined.

This method is open to several objections; however, the idea expressed here of making a separate determination for plotting against varying volume of lead solution has much merit.

In later tests by the Hartmann and Lewon method it was demonstrated that the density of the lead used in digestion had a great influence on the polariscopic reading.

These tests indicate the difficulty in relying on a purely polariscopic method for determining the sucrose content of the sugar beet.

What is needed is a chemical method for determination of sucrose which eliminates the errors caused by polarizable substances other than sucrose. Such a method could be used to calibrate the present tare laboratory practice.

One of the subjects on the agenda of the U. S. Committee of the International Commission for Uniform Methods of Sugar Analysis is Subject No. 26, "Sucrose in Sugar Beets." The objective of the referees on this subcommittee will be the development of a method for determination of sucrose in the sugar beet.

The active cooperation of all interested in this subject is requested.

Development of Sugar Evaporator Scale Preventatives

R. C. Ulmer and P. M. Caro[1]

Among other products, the authors' company supplies materials for water treatment and sugar evaporator treatment. In fact, in many cases products for both purposes are supplied to the same plant. The question is often raised as to why results are so predictable in the case of water treatment but so unpredictable and uncertain in the case of sugar evaporator treatment. Inferences are sometimes made that the products used in sugar evaporator treatment are not as effective as those used in boiler water treatment.

In a previous paper presented before the Cuban sugar technologists group (1)[2] the author discussed this subject in some detail and pointed out that there is a great difference in the present knowledge of water treatment and sugar evaporator treatment in that in the latter operation precise data are not available. This makes it impossible to logically approach the problem through the steps of first ascertaining exactly what the problem is and then prescribing a known and specific cure.

The remainder of this paper discusses some of the need for pertinent information and also indicates wherein some of the recently published data partly supplies the needed information. In view of the lack of complete information a research method is discussed which furnishes information which makes possible better usage of scale preventatives in the field.

Much of the difficulty arises from the fact that the defecation process is not clearly understood from a physical and chemical standpoint. About all that is clear is the purpose of defecation: namely, the precipitation and removal of non-sugars which will interfere in the following processes of evaporation and crystallization. The general physical requirements also are known; that is, it must be possible to remove the materials by sedimentation or filtration. Much of the control work in clarification is by trial and error and through such efforts it is now known how to generally handle the purification to obtain sludges which will settle rapidly and filter easily.

Far less is known about the chemical aspects of juice clarification and it is here that most of the trouble originates. Actually in most cases only one-fourth to one-half of the non-sugars are removed and as much as one-tenth of the sugar remains in the molasses. The situation exists because, at least in the past, of lack of chemical data regarding the juices. No complete analysis of beet juices is known and furthermore no suitable method of analyses exists for many materials "thought" to be present in beet juices. The situation is further complicated by the fact that the composition of beet juice varies greatly. There are great differences due to beet variety, climate, soil and fertilizer, plant diseases, degree of maturity, conditions of storage and juice extraction.

Referring more specifically to defecation, there still is no real workable theory of juice purification. Very little is known of ionic strength of the

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[2] Figures in parentheses refer to literature cited.

juice and solubility product data, especially for the various inorganic and organic calcium salts. This information would be quite complicated for a simple liquid; it becomes very complicated for a complex material like beet juice.

There is no intent in the above to belittle the beet sugar industry. It is realized that the chief objective is to make sugar and that for the reasons given above accurate data have not been obtained. It is interesting to note that active work is now being carried out on most of these subjects by the U.S.D.A.'s Western Regional Laboratory in this country and by Dedek and others in Europe.

In the work carried out by Dedek (2), an attempt is made in a general way to list the classes of materials in beet juice and to show their effect in the sugar manufacturing process. This information is summarized briefly in Table 1.

Table 1.—General Classes of Materials in Beet Juice

Acids
- a. with soluble lime salts—increase ionic strength of juices. May form complex salts.
- b. with insoluble lime salts—sulfuric, phosphoric, oxalic, tartaric, citric, etc. Form scale.
- c. amino acids—glutamic and aspartic are typical. These materials often interfere in the preliming.

Amides—glutamine and asparagine are typical. May give off ammonia forming amino acids.
Proteins and Peptides—are charged electrically. At isoelectric point may precipitate.
Pectins—Esterified polygalacturonic acids. Easily split. Shorter chain acids or neutral salts are formed. Calcium pectates rather insoluble—scale?
Polyphenols—may cause "amethyst" color.
Tyrosine—may cause dark blue colors in raw juice.
Saponins—cause foaming of raw juice, waste and pulp waters.
Nitrogeneous bases—Betaine is an example—act as buffers.
- a. ammonia—this is lost reducing alkalinity.

Iron and Aluminum—Scaling—removed by liming?
Sodium and Potassium—chief non-scaling cations present.
Silicic acid—present as colloidal and crystalloidal—scale.

Note: All of the above may act individually; in addition each may enter into side reactions with other materials present. Relative concentrations, solubility products, alkalinity, temperature, etc., all are controlling factors.

The tabulation in Table 1 indicates that the non-sugars in sugar beet liquors are varied and complex. In general most of the constituents present have characteristic properties but in addition each may enter into side reactions with other materials present. Relative concentrations, solubility products, alkalinity, temperature, etc., all are controlling factors.

More specific information is available from publications of Stark, Goodban and Owens of the Western Regional Research Laboratory (3, 4, 5). Processing liquors from several beet sugar plants were studied. Analyses were conducted for various anionic constituents and colloidal material. Organics were identified by paper chromatography. Separations were made by fractionation on ion exchange columns.

Briefly their work has disclosed no significant new compounds. Results show that except for anions forming insoluble calcium salts and colloids which are heat-denatured or precipitable in alkaline calcium-containing solution, few changes in composition occur during processing of sugar beet

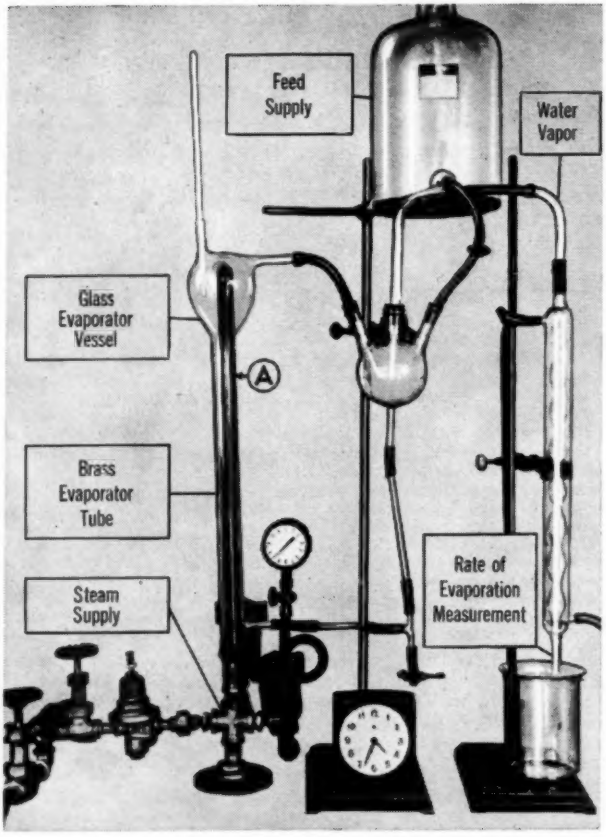

Figure 1. Apparatus for Determining Characteristics of Solutions.

Table 2.—Typical Analyses of Beet Processing Liquors.

	Raw Juice	Thin Juice	1st Evap. Juice	2nd Evap. Juice	3rd Evap. Juice	4th Evap. Juice	5th Evap. Juice
Total Alkalinity (as $CaCO_3$) in ppm.	738	769	1,089	1,378	1,529	2,307	4,104
Carbonate Hardness (as $CaCO_3$) in ppm.	738	123	162	222	308	359	598
Non-Carbonate Hardness (as $CaCO_3$) in ppm.	236	0	0	0	0	0	0
Total Hardness (as $CaCO_3$) in ppm.	974	123	162	222	308	359	598
Calcium (as $CaCO_3$) in ppm.	188	120	140	192	239	316	547
Magnesium (as $CaCO_3$) in ppm.	786	3	22	30	69	43	51
Chlorides (as Cl) in ppm.	68	318	530	640	675	978	1,984
Sulphates (as SO_4) in ppm.	180	239	330	490	520	800	1,700
Silica (as SiO_2) in ppm.	45	15	28	30	30	43	[1]
Excess Phosphates in ppm.	450	0	0	0	0	0	0
Oxalate[2] as C_2O_4 in ppm.	551	4	5	6	6	7	16

[1] Color Interference.
[2] May contain a mixture of organic acids.

diffusion juice. The analyses show that some colloidal material, oxalate, citrate and phosphate are removed by liming and carbonation. The amino acids and other acid radicals remain in the thick juice to increase the amount of molasses. Certain chemical methods which might improve defecation were mentioned: (1) preliming of the beets, (2) use of flocculators like alumina and (3) destruction of amino acids with chlorine.

Development of Sugar Evaporator Treatment

From the previous information it is evident that detailed and exact data and information are not available on beet sugar processing. Therefore, it is not possible to set down an exact "working theory" as a basis for eliminating evaporator deposits.

Some help can be obtained from analyses of sugar liquors at various stages of the processing operation and of deposits from various evaporator effects. Typical data are shown in Tables 2 and 3. It will be noted that sulfates, phosphates, oxalates and in general insoluble calcium salts of

Table 3.—Typical Beet Sugar Evaporator Deposit Analyses.

Constituent % by weight	Michigan Field	Intermountain Field	West Coast Field
Silica (SiO_2)	1.91	43.2	9.4
Iron (Fe)	5.21	2.6	3.7
Aluminum (Al)	3.11	1.9	1.8
Calcium (Ca)	20.80	11.5	13.5
Magnesium (Mg)	6.25	0.5	1.3
Sodium and potassium	0.73	....	....
Copper (Cu)	0.62	2.9	1.8
Heavy metals except Cu	Trace	....	Trace
Chlorides (Cl)	0.0	0.0	0.0
Sulphates (SO_4)	1.93	6.9	17.1
Carbonates (CO_3)	7.02	4.9	5.1
Oxalates (C_2O_4)	42.90	10.3	13.2
Phosphates (PO_4)	1.65	1.8	1.3
Loss on ignition, excluding CO_2	51.02	19.3	33.2
Loss at 110° C	3.68	....	....

Note: There is considerable variation depending on locality. In the case of oxalates, other organic acids may be included.

organic acids are instrumental in deposit formation. Also, it should be noted that the amounts of impurities are very high, indicating great scaling tendency. At first, attempts were made to study the problem in a laboratory evaporator using plant sugar liquors taken during actual sugar manufacturing. Difficulties were encountered immediately owing to "boiling problems," especially foaming and carmelization. Knowing the chief scaling constituents concerned, it was then decided to use "synthetic solutions" approximating the concentrations of certain inorganic and organic materials in beet juice.

The evaporation equipment used, Figure 1, has been described previously (6). Essentially the equipment consists of a brass tube simulating an evaporator tube, enclosed in a glass container. The feed solution is introduced continuously into the feed supply vessel, from which the solution circulates to the heating section around the tube. When steam is generated in the tube, it passes off through a trap to a condenser. The water condensed is an indication or measure of the amount evaporated and is collected and measured. The general procedure is to make up the synthetic water under study and add it to the feed supply. The equipment is first adjusted with distilled water in the tube so that the evaporation rate is at a predetermined value, usually 25 cc. per minute (approximately 9.6 pounds per hour per square foot). Once this adjustment is complete, the feed supply water is allowed to replace the water evaporated. The solution becomes scale-forming and a deposit will form on the tube, decreasing the heat transfer rate and consequently the evaporation. The measured rate will therefore fall off. The rate at the end of 60 minutes is generally used as a measure of the scaling characteristics of the solution under test.

Pertinent data for four types of synthetic solutions used without treatment and using six different scale preventive combinations are given in Table 4.

Table 4.—Results of Test Runs with Evaporator. Rate after 60 minutes.

Solution	Rate at Start	No Treatment	Dispersr S Starch Base	APA-M, EC; Phospho-Alginate	Organic C; Processed Cellulose	APA-ME; Phospho-ligno-sulfonate	Dispersr ME; Ligno-sulfonate base	Jam Pectin
$CaSO_4$	25	12.3	15.9	23.8	20.8	24.1	22.0	20.4
$CaSO_4$ + Oxalate	25	6.8	10.8	15.0	24.8	24.3	18.0	19.6
$CaSO_4$ + SiO_2	25	13.1	21.4	21.2	22.2	23.1	23.2	.....
Calcium Aconitate	25	15.5	15.8	15.6	15.4	16.1	15.7	.....

Note: All evaporation rates are expressed as ml/min. In all, some 52 different materials or combinations have been tested. The results given are typical of those considered most applicable to beet sugar evaporator treatment.

It will be noted that with no treatment the rate of evaporation drops off and is quite low at the end of an hour for all four types of liquors. All of the "treatments" shown in the table improved evaporation rates: APA-M, EC; Organic C, and APA-ME being the most efficient.

It should be noted that certain of the treatments are better for specific types of scale-forming materials than for others. For example, Organic C is very effective for $CaSO_4$ + Oxalate; APA-ME is effective for $CaSO_4$, $CaSO_4$ + Oxalate and $CaSO_4$ + SiO_2. The same is true of APA-M, EC

but this material appears to have its chief application for $CaSO_4$ type liquors. These facts indicate that some consideration must be given to the type of problem involved in deciding which treatment may be expected to give the best results. As liquors vary from plant to plant, or for that matter in the same plant, one treatment cannot be expected to serve all purposes. In making a decision regarding the treatment to be used, analysis of the juices in different stages of processing and of deposits formed are very helpful. An analysis procedure for juices has been published by Ulmer (1).

Referring to field usage of the types of treatment, two articles were presented before this society in 1950 dealing with APA-M, EC type; one by Gaddie (7), the other by Rawlings (8). Both discuss the results obtained, especially the reduction in boilouts per unit amount of beets processed and a consideration is given to the economic justification of the treatment. Treatments designated as APA-ME, Organic C and Disperser ME have been used in the field with good success.

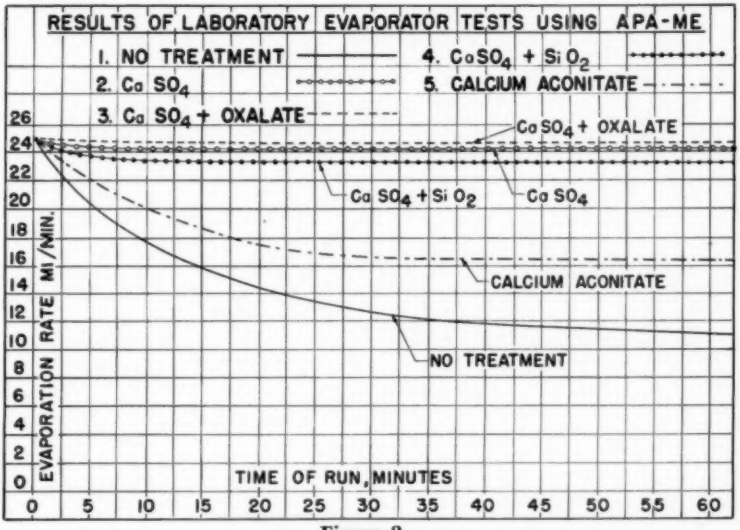
RESULTS OF LABORATORY EVAPORATOR TESTS USING APA-ME
1. NO TREATMENT
2. Ca SO4
3. Ca SO4 + OXALATE
4. CaSO4 + Si O2
5. CALCIUM ACONITATE
Ca SO4 + OXALATE
Ca SO4 + Si O2
Ca SO4
CALCIUM ACONITATE
NO TREATMENT
EVAPORATION RATE MI/MIN.
TIME OF RUN, MINUTES
0 2 4 6 8 10 12 14 16 18 20 22 24 26
0 5 10 15 20 25 30 35 40 45 50 55 60

Figure 2.

Discussion and Conclusion

A review of presently available data indicates a lack of authoritative information and theories regarding beet juice defecation and evaporation. Especially, specific data are not available which make possible valid predication of the scaling characteristics of a given liquor. Recent work fortunately is supplying much of the needed information regarding the composition of the non-sugars. Once this complete information is available, more precise studies can be carried out.

Realizing the great variation in non-sugars in beet juices, but having plant data on the general types of materials causing deposits, the scale problem in evaporators has been approached by using synthetic solutions approxi-

mating beet juices in composition. Using these solutions in a laboratory 'evaporator" treatments have been developed which reduce scaling.

As to the general usage of "treatments," to the author's knowledge, no chemical or physical treatment is available which will completely eliminate scale in evaporators. Those dealt with in this paper decrease scaling and appreciably decrease the number of boil-outs. In addition better over-all evaporator and boiler efficiencies result. These, with the saving of boil-out chemicals and labor generally justify the treatment.

Also, to the authors' knowledge, no single treatment exists which will work in all locations at all times. Analyses of sugar liquors during the processing operation and evaporator deposits have indicated a variation in the scaling materials. Such analyses are recommended as an aid in selection of the best possible treatment. Also, such analyses are recommended as a means for altering and controlling and possibly in improving defecation so as to obtain a less scaling liquor to be evaporated.

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Handling and Treatment of Dried Beet Pulp

C. D. Fox[1]

Among the problems encountered when the project at St. Hilaire was inaugurated was the problem of drying and handling of beet pulp. Most of the difficulties of drying were due to inexperience of the personnel and the normal difficulties incident to starting a new factory. Although conditions in this respect gradually improved, certain minor troubles were experienced in the bagging and carring of the pulp.

Due to the fact that we were operating the original Silver Diffuser, certain characteristics were noted which had not previously been encountered. It was found advantageous to supply the diffuser with extremely fine cossettes, often of a fineness giving in excess of 30 meters/100 grams. Probably due to the low temperature employed in the diffuser, the dried pulp was extremely tough and wiry and had a weight to volume ratio of only 7.5 lbs./cu. ft. There were times it was impossible to get a 100-lb. fill in the largest bag obtainable. This condition was intensified by the fact our pulp received very little mechanical handling, going by short screw conveyor direct to the elevator and by means of another short screw conveyor to the bagging station.

During cold weather another difficulty was encountered which we believe has always presented itself to manufacturers of beet pulp. This was the so called "sweating" of the pulp which we believe was caused by condensation and rehydration. Since this condition was sometimes worse than at other times without any apparent explanation, it was assumed that, under certain conditions which were not determined, the pectin in the pulp was quite readily rehydrated.

The remedy normally employed was to store the pulp in the warehouse for two or three days in low piles after which it was loaded in cars, involving considerable extra expense. The thought then occurred that if the pulp could be cooled before bagging and some of the residual moisture removed this trouble could be eliminated.

A machine was developed whereby the pulp was passed over a series of perforated screens with a counter-flow of air, as indicated in Figure 1. When this machine was perfected it was found that a cooling of 10° to 20° C. was obtained as well as a reduction in moisture of from 2.49 percent to 3.74 percent, depending on the moisture leaving the drying drums and the relative humidity of the air admitted to the cooler. This drying action was found to be of special value when the pelleting of the pulp was undertaken, about which more will be said later. It also made it possible to reduce the temperature of the gases leaving the drums by as much as 20° C. with a consequent saving in fuel.

Figure 2 indicates the relation of moisture before and after the cooler at various moisture content and Figure 3 indicates the relation of moisture leaving the drying drums and at the bagging station. The difference can be accounted for as due to drying action during handling other than cooling operations. Since the introduction of the cooler, pulp has been loaded directly into the cars without a single instance of "sweating" action.

The cooler is powered with a 10 h.p. motor. About 2,200 cu. ft. of air per minute are drawn through the cooler at an average relative humidity of

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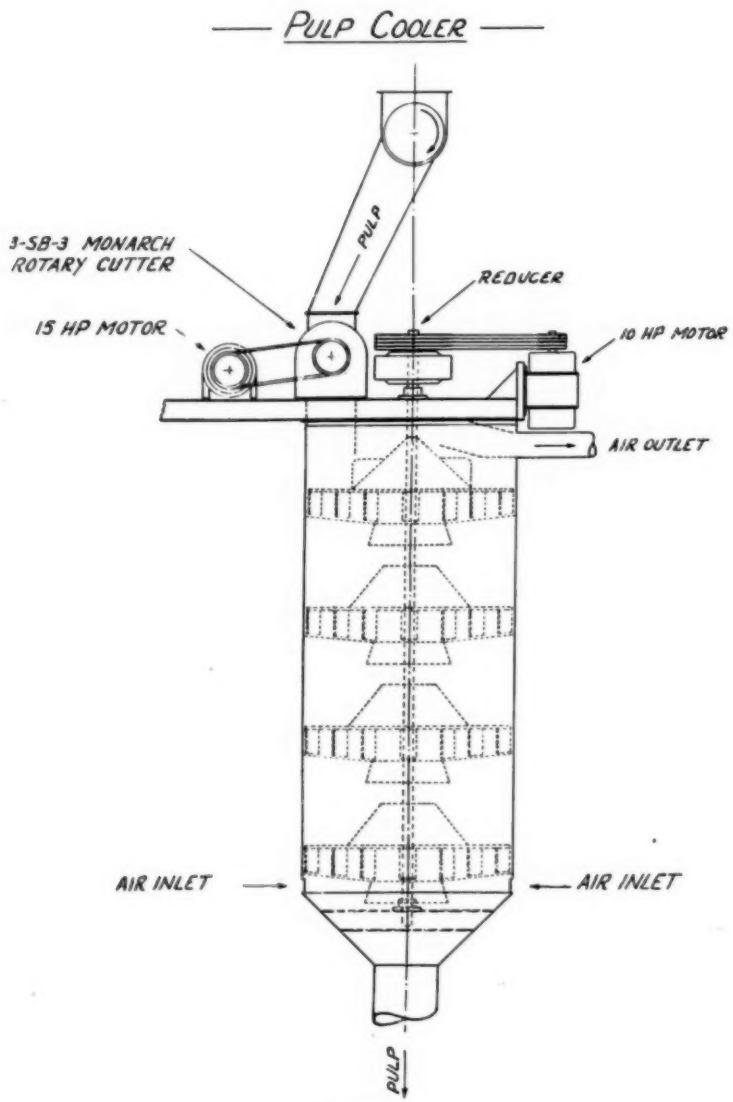
PULP COOLER
3-SB-3 MONARCH
ROTARY CUTTER
PULP
REDUCER
15 HP MOTOR
10 HP MOTOR
AIR OUTLET
AIR INLET
AIR INLET
PULP

Figure 1.

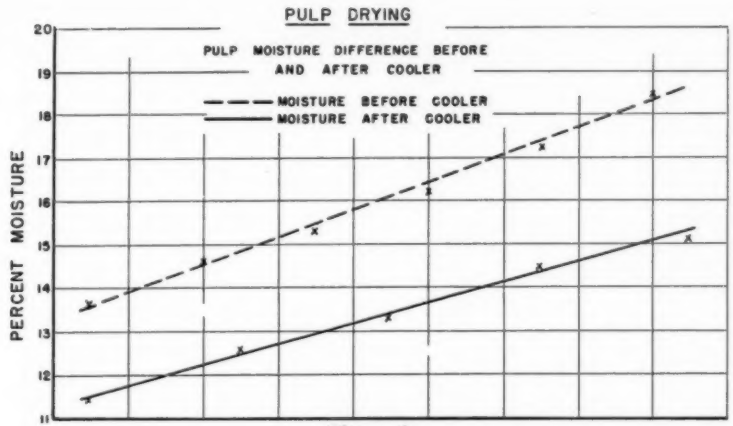

Figure 2.

50 percent, which is equivalent to 44,000 cu. ft./ton of pulp. A sufficient breaking action occurred in the cooler to densify the pulp to the point where 100 lbs. could be filled in a 36″ x 54″ jute bag.

The next problem which arose was the scarcity and the extremely high price of jute bags. It was decided to convert to 50-lb. paper bags as had already been done by certain other producers. For this program a further densification of the pulp was deemed necessary and was accomplished by the use of a Sprout-Waldron 3-SB-3 Monarch rotary knife cutter placed ahead of the after cooler. Certain other producers were already using this machine and we therefore claim no credit for this introduction. This machine is powered by a 15-h.p. motor and has a capacity of approximately 2.5 tons/hour, the density of pulp before cutting being 7.25/cu. ft. and after cutting 11.5 lbs./cu. ft. or an increase in density of 37 percent. After densifying it was quite easy to fill 50 lbs. of pulp into an open mouth paper bag of 21″ x 7″ x 53″ dimension.

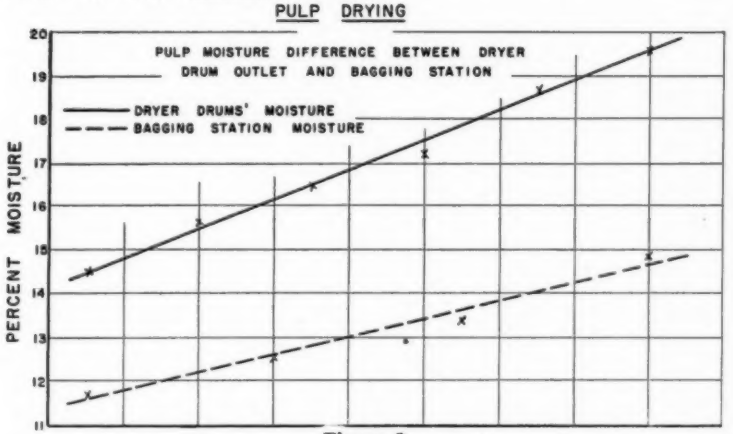

Figure 3.

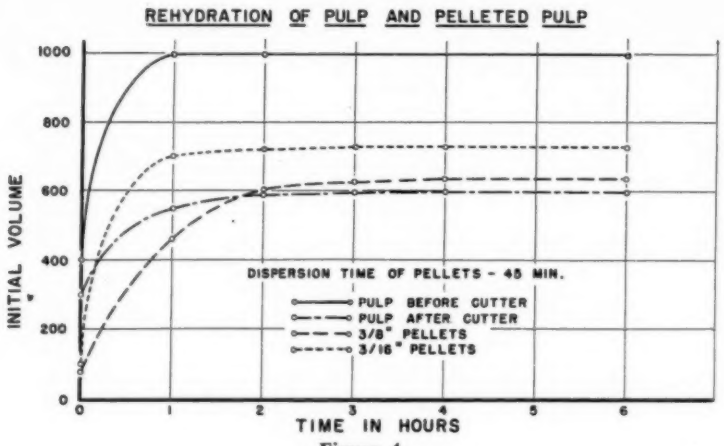

Figure 4.

The next project undertaken was the pelleting of dried beet pulp. At least one trial had been reported by another producer with favorable results. After conferring with a manufacturer of pelleting equipment, some of our pulp was successfully pelleted in a machine owned by a large cooperative in Montreal. Later on installation was made consisting of a Sprout-Waldron 501 "Simplex" pelleting mill, a pellet cooler was built at the plant to plans supplied by the above Company and a 4′ x 6′ vibrating screen for the removal of fines from the pellets. After the equipment was put into operation, certain revisions were required on the feeding and conditioning compartments of the mill. After these revisions were completed, pellets were successfully made, using both 3/16″ and 3/8″ diameter die.

It was found possible to pellet pulp at a moisture content of from 14 to 17 percent, the optimum content being in the 15 to 16 percent range. The machine is equipped with a conditioning compartment wherein steam is introduced to bring the pulp to the desired moisture and temperature. It was here that an additional value of the after cooler was found. If pulp was sent to the pellet mill at the normal moisture content of 12 percent, the steam requirements for conditioning were excessive and, in fact, the capacity of the conditioner was inadequate. Another complicating factor was the fact that the single mill installed could handle only one-third to one-half of the pulp produced.

The solution was to bring the pulp from the drums at approximately the right moisture content for pellet operations. For the remainder of the production above pellet mill capacity, sufficient additional drying was obtained in the after cooler to render it suitable for bagging. The optimum temperature for pelleting was found to be 180° to 185° F. The moisture of the pellets leaving the mill averaged 14 to 16 percent, and leaving the pellet cooler 10.5 to 13 percent.

The 3/16" pellets had a density of 38 to 40 lbs./cu. ft. and the 3/8" pellets 37 to 39 lbs./cu. ft. It was found possible to fill 100 lbs. of either size into an open mouth paper bag of 17.5" x 4.5" x 41", costing considerably less than a single 50-lb. paper bag. The space required for storing and shipping the pellets is less than one-third of that for unpelleted pulp. Pellets are well adapted to bulk storage and shipping.

It was found advisable to determine the time required for dispersal in water of these pellets and also to what extent the time required for rehydration was affected as compared to unpelleted pulp. The time required for complete dispersion for both the 3/16" and 3/8" pellets was 45 minutes.

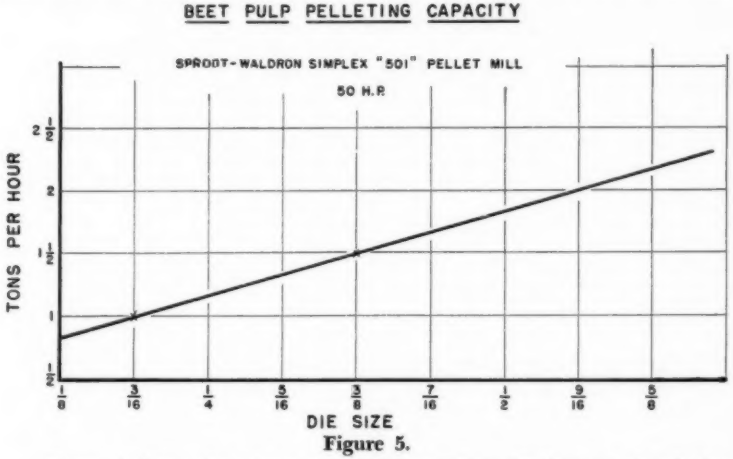

Figure 5.

Figure 4 shows the time required for complete rehydration of pulp before and after cutting the 3/8" and 3/16" pellets. This graph indicates that the total rehydration time of the pellets is in direct ratio to their diameter. As yet the use of additives in pelleting operations has not been tried but is being considered. The cost of pelleting per ton of pulp was found to be as follows:

Labor	$1.00
Electric Power	.12
Steam	.04
[2]Miscellaneous	.25
Total	$1.41

On the basis of the 1951 campaign, comparative costs for bagging and handling dried beet pulp in various forms and containers were as follows, using cost of bagging and handling in 100 lb. jute bags as 100:

Pulp in 100 lb. jute bags	100 %
Pulp in 50 lb. paper bags	48.3%
Pellets in 100 lb. paper bags	22.5%

ACKNOWLEDGMENT: The writer wishes to make acknowledgment to Gerard Audet, mechanical engineer; Fernand Begin, process engineer, and Real Leduc, chief chemist, for performance of work and compilation of data.

[2] Includes maintenance on equipment.

Direct Filtration of First Carbonation Juice

HUGH G. ROUNDS AND ROBERT B. THOMPSON[1]

Part I.

In recent years while studying the problems of carbonation and lime salts control we have become increasingly concerned about the reduction in juice quality and increase in color which occurs during the detention time in the thickening and settling tank after the first carbonation.

As our measuring sticks of juice quality in this case we have used the alkalinity and also the effective alkalinity of the juice entering and leaving the thickener; the effective alkalinity will take into account any change in lime salts as well as changes in alkalinity. Color changes were noted both by visual comparison and optical density measurement by spectrophotometer.

While the amount by which the juice changes during the clarification does vary, probably due to changes in beets, or carbonation, we have never found it to be negligible. During the latter part of the 1950-51 campaign at our Nampa, Idaho, factory, a straight house, we conducted approximately fifty tests on first carbonation juice entering and leaving the thickener. Detention time in this thickener is about one and one-half hours. The results are summarized in Table 1.

Table 1.

First Carbonation Juice	Alkalinity, % CaO (Phenolphthalene Neutrality)	Effective Alkalinity	Optical Density[1]
To thickener	.069	+ .001	1.0
From thickener	.059	— .019	1.2

[1] Using a 10 brix sugar solution as standard.

The thickener cannot easily be replaced for it is an economical and efficient means of separating the juice from the precipitates. Nevertheless, we cannot hope to minimize our carbonation and lime salt problems while suffering severe degradation in juice quality during clarification. For this reason the Amalgamated Sugar Company, in cooperation with several manufacturers of filtering and separating equipment, investigated the feasibility of using direct methods of clarifying first carbonation juice, where the use of such methods would greatly reduce the time between the first and second carbonation and yet be economically practical.

Tests were conducted using two different types of centrifugal separators neither of which proved to be satisfactory for this particular purpose for the following several reasons:

1. While the resulting clarified juice did show some slight improvement in alkalinity and effective alkalinity, it was also turbid and accompanied by a great deal of foam. It is believed that this turbidity developed from a partial redispersion of the fine particles in the floc caused by the sudden application of large centrifugal forces and agitation within the separator. The juice remained turbid even after several repeated filtrations using a filter aid.
2. Each type of separator was equipped with sludge washing device, but neither displayed evidence of being capable of reducing the sugar content in the precipitate sludge to more than a slight degree.

[1] Research Engineer, Amalgamated Sugar Co., and Consultant, The Eimco Corporation, respectively, Mr. Rounds author of Part I, Mr. Thompson author of Part II.

3. Certain individual design characteristics of each machine make their use undependable and undesirable for this purpose.

A pilot model vacuum drum type filter was furnished by the Eimco Corporation which was similar in most respects to those ordinarily used for separating juice from thickener sludge. The original submergence was approximately 30 percent, and provision for washing both the filter cloth and the lime cake was made. The filter was fed directly from the first carbonator. The averages of the first group of tests run under these conditions are shown in Table 2.

Table 2.

Alkalinity % CaO	
First Carbonator Effluent	.071
Filtrate from Filter	.068
Clarified Juice from Thickener	.061
Effective Alkalinity	
First Carbonator Effluent	.000
Filtrate from Filter	—.002
Clarified Juice from Thickener	—.017
Color as Optical Density	
Filtrate from Filter	.9
Clarified Juice from Thickener	1.2
Filter	
Capacity GPM/Sq. Ft.	.42
Lime Cake Wash Water, Gal./Gal. Juice	.19
% Sugar on CaO in Washed Lime Cake	2.7

These results show that direct filtration caused very little degradation of the juice. However, capacity was low and an excessive amount of water was used in washing the cake resulting in an equivalent sugar loss of .08 percent on beets, which is itself too high. The filtrate clarity in most cases was not good.

A top-feed was then installed on the filter. This allowed a portion of the incoming juice to flow onto the filter cloth during the drying phase, thereby increasing, in effect, the submergence to about 50 percent. The averages summarizing the tests conducted with the top-feed in use are shown in Table 3.

Table 3.

Alkalinity % CaO	
First Carbonator Effluent	.074
Filtrate from Filter	.068
Clarified Juice from Thickener	.061
Effective Alkalinity % CaO	
First Carbonator Effluent	+.001
Filtrate from Filter	.000
Clarified Juice from Thickener	—.019
Color as Optical Density	
Filtrate from Filter	1.1
Clarified Juice from Thickener	1.2
Filter	
Capacity, GPM/Sq. Ft.	.67
Lime Cake Wash Water, Gal./Gal. Juice	.10
% Sugar on CaO in Washed Lime Cake	2.0

These figures show again that the quality of juice from the filter was a great improvement over the clarified juice from the thickener. Other factors including capacity, wash water used, sugar remaining in the cake, and clarity, all showed improvement, but the averages for these factors did not reach what most of us would consider an economic level, unless a factor representing the improvement in juice quality and color is applied. It should be pointed out that in certain individual tests capacities as high as one GPM/sq. ft. were attained; also that a sugar loss in the lime cake as low as .02 percent on beets was obtained in one test using the average amount of wash water.

The results of these tests have led us to the conclusion that the use of direct filtration on first carbonation juice will provide us with a juice of higher quality and less color than juice as clarified by the thickener; that, if such filtration is accomplished by a vacuum drum type filter as was furnished us by the Eimco Corporation, the possibility exists, though it will need development, of reducing the sugar content in the lime cake to an economical value in the single filtration; that if a capacity of one GPM/sq. ft. could be maintained in such a filter the required area necessary would exceed slightly the filter area now used in our installations for handling the thickener settled lime. The improvement in juice quality and color alone is a temptation to return to direct filtration of first carbonation juice, as these should reflect in a more efficient operation. Also, if the possibilities of this type of filter can be developed, we might well have as efficient a method of separation as is the thickener.

Part II.

Our purpose in this study was to investigate the possibility of filtering a given product under a given set of conditions. I can rightly express and defend opinions directly connected to the filtration of first carbonation juices.

As described by Mr. Rounds[a], the mission of the Eimco Corporation was to answer three questions: 1. Is it feasible to filter carbonation juice without thickening and so remove the lime and precipitated impurities from it? 2. What are the ways and means that the filtering rate can be increased, the process simplified and made more attractive to the users? 3. What are the principal items of design involved in such a filter installation?

To answer these questions we elected to use an Eimco continuous drum type laboratory vacuum filter. The 18″ diameter by 12″ long drum with all auxiliary equipment was mounted on a platform so that the unit was self-contained and no variables from plant operation were introduced. With control, then, of all variable factors except the feed consist our results can be readily correlated to plant practice.

Experience has shown that results from the continuous laboratory filter are exactly comparable to the results obtained in plant practice in all but one respect. Washing efficiency on the laboratory filter is lower than on the commercial sizes. This irregularity stems from the fact that there isn't room enough on the small drum to apply as much wash water as the cake will pass.

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[a] Part I this article.

So much then for the generalities surrounding this test work. Now to get down to what we learned in the course of the investigation.

1. The direct filtration of first carbonation juice is practical. We found that the average filtration rate can be expected to approximate 0.65 to 1.00 gallons per square foot per minute or more. Assume for a moment that we are to filter a maximum of 650 gallons per minute. Then $\frac{650.00}{.65} = 1{,}000$ square feet of filter area required. Two 11'6" x 14' filters have 1,008 square feet of area. The area required for these filters would approximate that required for a 25' tray thickener to handle the same quantity of juice. The vertical height would be much less.

The cake thickness obtained was about 1/8 inch. This thin cake was the result of the low percentage of solids in the feed, only 2 to 3 percent. Actually the cake discharged rather well. Since moisture content of the cake is not an important factor, cake washing can be continued almost to the point of discharge.

Since the principal problem is to pass large volumes of juice through the filter we raised the level of drum submergence. In this instance we feel that a 50 percent submergence is desirable. This submergence is practicable and is frequently used in the petroleum and chemical industries.

As to filter media we found no cloth more suitable than a 14½ oz. cotton twill. We tried nylons, vinyons, orlons, sarans, steel mesh and lighter cottons down to 12 oz. twill. Cloth life is prolonged by use of a continuous cover washing shower located just below the scraper blade. This continuous cover washing lessens the necessity of frequently manually washing the filter cover with acid solution. We found a practically constant decrease in filter rate over an eight hour period and at the end of that period we washed the filter blanket with a mild acid solution. The filter rate returned to its original high level. As a result of this experience, we recommend that the water supplied to the cover washing shower be treated with acid on a periodic basis—perhaps 10 minutes out of each hour. In the presence of a large amount of lime this small amount of acid will present no corrosion problems except in the wash header pipe and its spray nozzles. This periodic acid dosing will lessen or eliminate the constant drop in filtering rate experienced in our test work, and result in a higher rate of filtration than here reported.

Reduction of sugar content of the cake is accomplished by means of cake washing. Spray pipes supplying fresh water are located above the drum. These pipes may be located on about 15" centers. The sugar reduction will be in proportion to the amount of water passed through the cake. If it is desired to lessen the amount of water added, it can be done by counter currenting the wash liquors over the filter surface. This counter currenting can be accomplished through a three solution valve. Our experience indicates that about 95 percent of the sugar content of the cake is removed. Sugar determinations on the lime cake indicate a loss of .04 percent of sugar on beets.

The vacuum requirements for this system are relatively low. Not over 3 CFM per square foot of filter area need be supplied. At the Nampa plant we found that 15" Hg. was the maximum vacuum we could sustain without flashing. This flashing point is dependent on temperature and elevation. It should be determined for individual installations. A barometric condenser will control the flashings.

General Comments

Because of the high lime content of the pulp to be filtered extreme liming conditions should be anticipated in interior piping in filter design. This type of design has straight pipes connecting at right angles. A reamer on a flexible cable can be run through the piping in a short time.

There are no corrosion difficulties involved in the problem and so carbon steel construction except in the wash header will be suitable.

Temperature drop through the filter used at Nampa was 15° C. This drop would be lessened by insulation of the filter tank, receiver, etc.

Let us sum up then the principal items of filter design and technique which I have enumerated:

1. The filter rate may be expected to approximate .65 up to 1.0 gpm/sq. ft. or more.
2. Cake thickness will approximate 1/8" which will discharge well with a scraper blade.
3. 50 percent submergence is desirable.
4. A 14½ oz. cotton twill filter cover is suitable.
5. A continuous cover washing shower with periodic acid treatment is desirable.
6. A barometric condenser is necessary to control flashing.
7. About 3 C.F.M. of vacuum capacity per square foot of filtering area should be provided.
8. Filter design should provide for possible severe liming conditions.
9. Carbon steel may be used throughout except in the cover washing shower pipe and its sprays. These should be of material resistant to Hydrochloric acid.
10. Washing efficiences of about 95 percent to 98 percent can be obtained.

Recovery of Granular Fertilizer from Ion Exchange Spent Regenerants

J. R. JOHNSON[1]

Ion exchange operation in the sugar industry has shown itself to present three major effects.

1. Increased yield of low ash, low sulfite granulated sugar per unit of beets over conventional methods.
2. Economic effects varied by existing costs of equipment, regenerants, and the selling price or demand for final molasses.
3. Broader scope of possible by-product recovery from the beets and spent regenerants.

This paper is a study of the spent regenerant phase in the production of a granular complex ammonium sulfate fertilizer when sulfuric acid and aqueous ammonia are used as the regenerating mediums.

Preliminary experiments were conducted to develop methods of control analysis, to establish maximum pH levels, to investigate preferable boiling procedures and to determine drying temperatures and finished product characteristics (1)[2].

This work set up the following criteria:

1. A pH of 4.5 was found to be maximum to prevent nitrogen loss during concentration and crystallization. Lower pH's are undesirable from a corrosion standpoint.
2. Crystallization in a vacuum pan is best achieved by starting with a footing from the preceding pan.
3. Centrifugal work is best accomplished by drying in the centrifugal to about 8-9 percent moisture before discharging the product to the dryer.
4. The dryer should be operated at not less than 120° C. and should have adequate capacity to handle a fairly large recirculating load. The crystals are very hydroscopic when dried below 120° C. but when properly dried or calcined the mother liquor is charred or baked on the crystal surface and results in a product easily stored in paper bags and easily applied to the soil from drills, etc.

Pilot plant studies consisted of dropping 25 consecutive pans or batches by the in-boiling method described below the measuring yields, etc., throughout the entire operation (2).

The schematic diagram (Figure 1) of the process flow will aid in following the steps in production as taken up.

Spent regenerants were taken directly from the spent acid and spent ammonia tanks and mixed in a volume ratio of 1 volume of ammonia to 1.04 volumes of acid. This yielded a feed liquor with a pH of 4.5 on the average. Each batch was adjusted to 4.5 by varying either acid or ammonia when necessary.

The mixed solution is then pumped to the evaporator feed tanks where measurements and samples are taken for control data.

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[1] Chief Chemist Amalgamated Sugar Company.

[2] Numbers in parentheses refer to acknowledgment of work by others (listed at the end of this article).

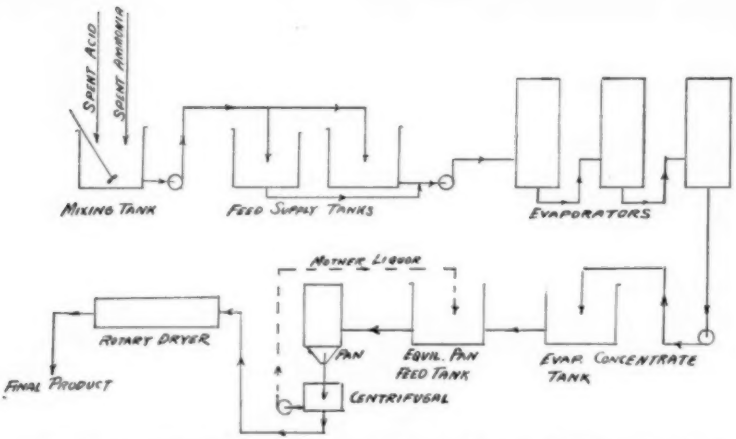

Figure 1. Schematic diagram ammonium sulphate fertilizer pilot plant. Amalgamated Sugar Company, Twin Falls, Idaho.

The evaporators consisted of three effects, the first operating at about 20 p.s.i. and the third under about 15 in. vacuum. Vacuum was provided by a barometric leg condenser. The thin feed enters the evaporators at about 4-5 percent solids and is discharged at about 30 percent solids.

The evaporated liquor was pumped into a primary pan storage tank from which it was measured into the equilibrium pan feed tank.

The equilibrium pan feed tank was operated by first admitting the green liquor spun from the fillmass produced in the preceding pan. The amount of this material is regulated somewhat by allowing the proper amount of mother liquor to remain on the crystals. Next evaporated liquor from the primary pan storage tank is pumped into the equilibrium tank to make up a definite volume of feed necessary for the next pan.

The pan used in this work was a 12 cu. ft. experimental sugar pan constructed from mild steel and equipped with four sets of internal steam coils. Vacuum was provided from a barometric leg condenser assisted by a steam-air-ejector. The pan also was equipped with a mechanical circulator.

The steam pressure on the coils was held at 100 p.s.i. so as to not cause scaling or burning on the coil surface.

Operating conditions were held as uniform as possible but water pressure fluctuations beyond control caused a little difficulty at times. A boiling temperature of 70 to 75° C. is desirable and the fillmass should be fairly loose for best circulation.

By varying the amount of fillmass left in the pan for a footing the desired grain size can be attained and an equilibrium is soon set up throughout the process. In boiling and dropping 25 consecutive pans little difficulty

was encountered in maintaining the proper ratios by in-boiling method. This, we feel, indicates that this method can be carried out indefinitely.

Separation was accomplished in a basket-type centrifugal. Washing is not desired and cycle time regulates the mother liquor retention by the crystals. The green is sent back to the equilibrium pan feed tank as mentioned above.

The dryer consisted of an inclined cylindrical shell, 2.5 ft. in diameter by 12.0 ft. long, similar in characteristics to the conventional granulator. A recirculating scroll was used to feed a blend of partially dried material and wet material into the head end. Heat was applied by means of a kerosene burner which forced the hot air through the dryer and out the stack. Temperature was maintained from 120 to 135° C.

The dried product is black in color due to the film of mother liquor baked on the crystal surface. It has the general shape of commercial ammonium sulphate and is easy to handle.

A typical analysis of the fertilizer produced at Twin Falls is as follows, calculated to approximate combination as single salts:

Ammonium Sulfate	71.5 %
Potassium Sulfate	12.7
Sodium Sulfate	4.9
Calcium Sulfate	1.7
Magnesium Sulfate	0.6
Silica	.05
Phosphate	.02
Amino Acids by Difference	8.5
Total	99.97

The actual forms of combination are uncertain as ammonium and potassium sulfates can form in any proportion. There is also a possibility that glaserite ($3K_2SO_4 \cdot Na_2SO_4$), glauberite ($CaSO_4 \cdot NaSO_4$) or other double salts may form under some conditions. Hydrates seem improbable under the existing operating temperatures but may form.

Screen analysis reported in accumulative percentages:

+ 30 mesh	24.4%
+ 50 mesh	68.6
+ 100 mesh	97.7
— 100 mesh	2.3

During the experimental run we produced a total of about 4 tons of dried crystaline fertilizer material.

The extraction figures show a loss of dry substance through the evaporators and pans of 11.9 percent, and a dryer loss of 6.85 percent, resulting in an actual yield of 85.1 percent. Due to the fact that on some batches we found that pH's were over 4.5 and at times we found entrainment to occur in boiling, we feel it is safe to estimate a yield of at least 90 percent in a full scale operation where a more uniform control can be attained. Amino nitrogen loss was found to be negligible but on the other hand total nitrogen

loss was high, which bears out the pH error mentioned above. We had some dust loss through the dryer which in a full scale operation could be minimized.

As an estimated figure for actual fertilizer production based on the Twin Falls ion exchange operation and on the facts found in the pilot operation we can realize at least 27.5 pounds of fertilizer per ton of beets sliced or about 275 one hundred pound bags per each 1,000 tons sliced.

This process has not been fully projected into a possible full scale operation as yet but we would like to point out a few possibilities and suggestions.

Successful pilot runs have been made employing continuous crystallization equipment such as manufactured by Swenson Evaporator Company and by Struthers Wells Corp.

In any type of operation particular emphasis must be placed on having a large drying capacity as this is one place where a bottleneck can develop if sufficient capacity is not planned for.

There is evidence that continuous centrifugals such as the type put out by the Bird Machine Co. or a drum type filter may replace the basket type centrifugal.

Mild steel probably would not withstand the low pH for any length of time; however, we found no bad conditions existing during our brief run. No. 316 stainless test plates indicated that this material would last indefinitely.

In actual practice if a pond area is available and if a C.S.F. plant is also contemplated the same boiler and evaporator installations could be used by making a C.S.F. run, then later pumping the spent regenerants from the pond for a fertilizer run. This would greatly reduce installation costs.

In reviewing the above procedure it is readily seen that, by in-boiling and by not washing at the centrifugal, we have eliminated an end product or molasses. The reason for this was that we could not see a ready market for this viscous material even though it is a good fertilizer base for liquid application.

By washing and producing an end liquor we can produce a light colored granular fertilizer which has suitable drying characteristics should a market develop for the end liquor.

After two years of ordinary storage the material we produced is still in first class condition.

Comparisons made with regular ammonium sulfate and spent regenerant fertilizers (3) applied to sugar beets and based on unit nitrogen content resulted in increased yield of tonage and sugar per acre (3).

From the application tests we found spent regenerant to be equal on unit basis to other ammonium sulfate fertilizers.

ACKNOWLEDGMENT

(1) Ray T. Jacobs, The Amalgamated Sugar Co. 1948.
(2) H. G. Rounds, The Amalgamated Sugar Co. 1949.
(3) C. P. Parrish, The Amalgamated Sugar Co. 1949-50.

The Necessity for Developing Adequate Pilot Plant Facilities for the Advancement of Beet Sugar Technology

FRANK N. RAWLINGS[1]

In this presentation we are not presuming to present any new data. It is well, however, to take stock periodically and see where we are and what is holding us back. From this it is quite often possible to learn what changes in course will result in more rapid advancement.

In looking at the present beet sugar technology and comparing it with thirty and forty years ago, two very different reactions can be obtained depending on the viewpoint from which the observation is made.

Take the rose colored viewpoint first and, may I add, in many ways a highly justified viewpoint.

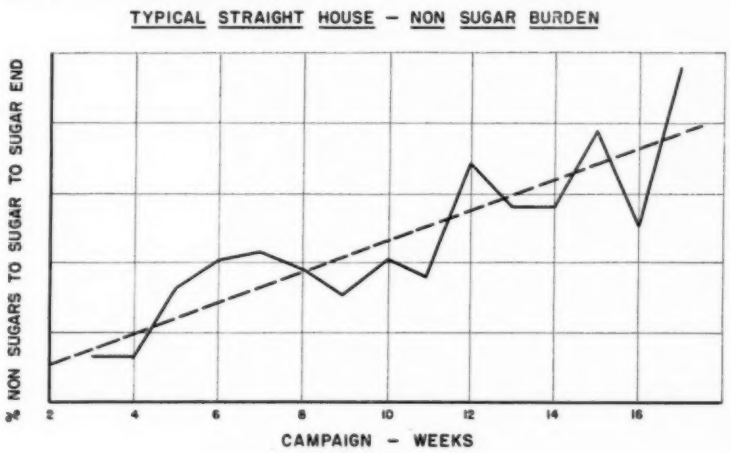

Figure 1.

The present day design of a new factory is a thing of beauty to behold in comparison with those factories built thirty and forty years ago. The performance today with its smooth flow of products through process with close control of additions, purity, etc., and the uniform high quality of sugar produced is a striking contrast with the lurching performance coupled with widely fluctuating house conditions of everything from battery supply temperature to raw pan purity and sugar quality which used to be the rule rather than the exception. There have been real advancements in the unit process equipment used in beet processing and in the instrumentation for control of these unit processes.

Looking at the advancement of beet sugar technology from this viewpoint, the people who have been instrumental in these developments can take pride in their handiwork.

[1] Director of Research, Amalgamated Sugar Company.

Now, looking at beet technology from another angle, we get a somewhat different picture.

Beet processing has for many years been a tremendous tonnage operation on a world scale. It might reasonably be expected that the composition and properties of the sugar beet, which is the basis of this industry, would be thoroughly understood. On the contrary, until the last two or three years no reliable and comprehensive beet composition data has been available. The answer hinged on the development of analytical techniques for this particular problem. The answer is just now beginning to unfold through efforts such as the work of the U.S.D.A. Western Regional Laboratory under the direction of Doctors McClay and Owens. Think of how many years of effort

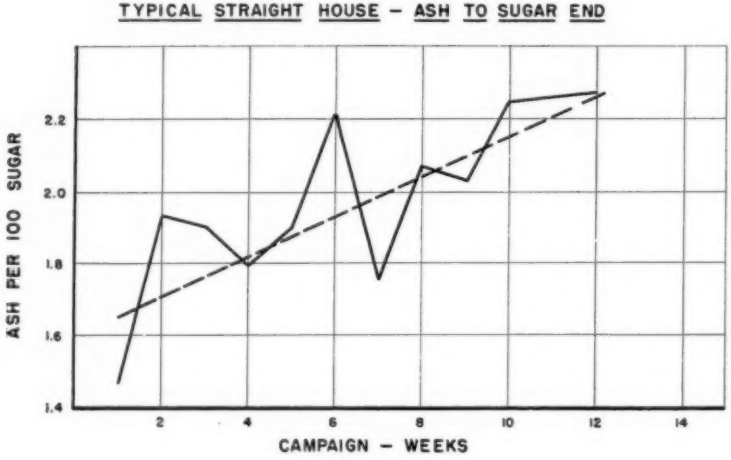

Figure 2.

have been spent by so many men groping for the behavior of beet juices and beet products without real knowledge of the reactants they were dealing with.

These results from the Western Regional Laboratory are among the finest examples of what may be expected from the application of adequate laboratory and pilot plant facilities coupled with adequate manpower to the problem of sugar beet technology.

Looking further into progress of sugar beet technology and passing into the factory itself the first operation is the slicers. How fully is the effect of chip quality on diffusion elimination known? How sure is anyone as to what represents the optimum chip? Everyone is reasonably sure that a good chip is tied into high elimination, but to our knowledge the details from there on are lacking. Certainly the cheapest purification that will ever be devised in beet processing is diffusion elimination. It, therefore, seems axiomatic that the industry should understand fully the mechanics of chip preparation and diffusion itself.

Now, moving on to diffusion itself. Where can you find well substantiated information on the following?

1. Effect of temperature of diffusion on the elimination of various classes of nonsugars.
2. Effect of time of diffusion contact on the elimination of various classes of nonsugars.
3. Effect of degree of exhaustion on elimination.
4. Effect of return of process waters on elimination.

Several more variables of diffusion could similarly be listed. A similar set of questions could be set up on the beet end purification steps of heating and carbonation, etc., which cannot be answered with any more certainty.

Why after so many years of operation is the physical and chemical behavior of this sugar beet and its products so much in doubt? Why is this sugar beet still viewed as being imbued with mystical properties by many operators? Such mystical associations have always been related to a lack of understanding or fundamental knowledge.

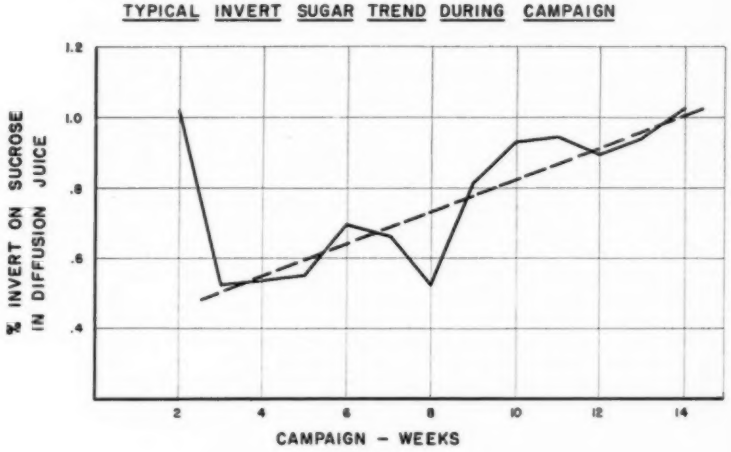

Figure 3.

An examination of the various reported studies on phases of sugar beet processing leads to the conclusion that the fundamental reason why such conflicting, confusing, indecisive reports have been forthcoming on many factors of beet processing has been the attempt to evaluate these problems on a factory basis. This is particularly true where the differences looked for are small.

Two very major problems confront anyone attempting the evaluation of a variable on a factory basis.

The first is the variability of the raw material itself. This variability is demonstrated in Figures 1, 2, 3 and 4. These graphs are based on weekly composites sampled on two or four hour samples. They demonstrate the

characteristic campaign variability of four important constituents of sugar beet liquors—namely, ash, invert sugar, amine compounds and total nonsugars. These graphs demonstrate a wide random deviation from week to week, superimposed on a basic rising trend in all cases except that of the amine compounds. It should be remembered that these are weekly composites, which will tend to iron out some of the variability occurring from hour to hour and day to day.

The second major complication in making comparative studies on a factory basis is the multiple internal cycles in the highly integrated sugar house balance. An example of the extreme variation which may result from shifts of these internal cycles is the variation in amounts of nonsugars which are returned to higher grade products via raw sugar. Circumstances have been detected where with poor raw sugar up to 40 percent of the nonsugars passing through the raw pan are returned to process via the raw sugar. On the other hand, with well purged raw sugar, this figure goes to 5 percent or less.

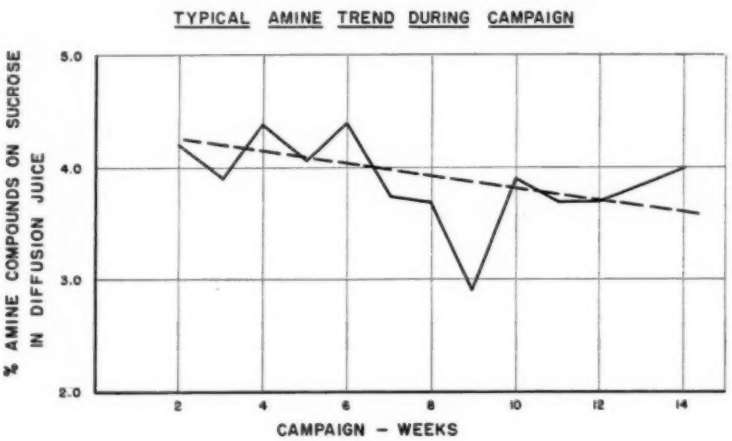

Figure 4.

An examination of the problem presented by this wide process variability as demonstrated above leads to the conclusion that an unwieldy number of repetitions and a maze of statistical analysis is necessary to reach a valid conclusion of even one small variable of sugar beet processing. We are faced with the need for answers to a large number of such problems.

There does appear to be a much shorter road to answering these problems and that is establishment of adequate pilot plant facilities for sugar beet studies.

In planning for any such pilot plant facilities, consideration should be given to planning for control of all variables involved in the problem.

Too many examples are on the books of sugar beet studies which were doomed to failure before they started because the equipment was poorly conceived and inadequately developed.

Due to the variability of sugar beet materials much of the pilot plant work will require preparation and preservation of sufficient quantities of a single sample so that this may be divided into a several of aliquots so that a series of variables may be run on a single source material. When this is done and all of the surrounding conditions are held constant with the exception of the one variable being studied, then—and only then—can real confidence be placed in the results.

Fortunately the availability of refrigeration equipment for rapid cooling or freezing of sizable quantities of samples, and the advent of many effective bacteriostatic and bacteriocidal materials which do not interfere with the studies, has simplified this problem of holding sufficiently large samples of materials for study.

Another factor which cannot be given too great an emphasis in planning for sugar beet processing studies is the preparation for adequate analytical control. Up to the present, inadequate analytical methods have seriously handicapped understanding of sugar beet processes. The analytical tools are now being placed in our hands for adequate analysis through such mediums as chromatographic analysis, but there are too few facilities in the industry to utilize them.

The considerations above bring us to the conclusion that only as the sugar beet industry obtains and adequately mans such pilot facilties will substantial progress be made. The improvements, obvious through casual investigation, are becoming lesser in number.

Bacteria Investigations in a Silver Diffusor

J. E. MAUDRU[1]

During the 1950 and 1951 campaigns Holly has been investigating bacterial activities in the Silver chain type batteries at the Carlton, California, and Sidney, Montana, plants.

The bacterial problems encountered in a continuous type battery are much more serious than those found in the conventional Roberts cell type battery, primarily because in the Roberts type the cells are dumped and thoroughly washed every hour while in the continuous type no such cleaning procedure is practical. The bacterial population must be controlled either by temperature or by addition of a bactericide.

Bacterial activity manifests itself by a lowering of pH of the battery juices, loss of sugar in the juices due to acid inversion, and an alteration of nonsugars so that the resulting juice is difficult to process. pH's of juices from the individual cells of a continuous battery may be as low as 5.5 and if a minimum pH of 6.0 is to be maintained some treatment such as formaldehyde or else high temperatures must be employed. An investigation of pH's of juice from individual cells in a Roberts battery operated in the usual manner showed a minimum pH of 6.3.

The first investigation performed was that of determining the thermal death points of the bacteria involved. An infusion of equal weights of cossettes and cold sterile water was mixed for thirty minutes and six plates in duplicate were inoculated. After mixing, the plates were exposed to temperatures ranging from 55 to 85° C. for thirty minutes. The plates were then incubated and counted in the usual manner.

Figure 1 shows the results of this study. It should be noted that the ordinates of this figure and all following figures are on a log scale. A log plot is necessary to cover the range from 1,000,000 organisms per ml. down to zero. Such a plot is confusing since a drop in population from 100,000 to 10,000 represents a 90 percent kill and yet only a 20 percent decrease on the vertical scale.

Referring to the data presented in Figure 1, a number of different species of each type of bacteria are present in the cossettes and each specie has a slightly different death point. If only one specie were present the count would remain constant to the death point and then drop to zero. This is shown in the curve on molds in which about 50 percent are killed between 60 and 65° C. At 80° C. yeast, mold, and acid producer counts drop to insignificant levels while the total count drops from 400,000 to 17,000

It appears then that temperature above 80° must be employed if temperature sterilization is to be effective. Nineteen hundred fifty-one campaign averages for maximum battery temperatures are Carlton 78° C, Sidney 70° C., average for Roberts type battery 84° C., minimum for Roberts type 79° C. It appears that freedom from bacteria trouble in the Roberts type battery is at least due in part to higher temperatures.

[1] General Chemist, Holly Sugar Corporation.

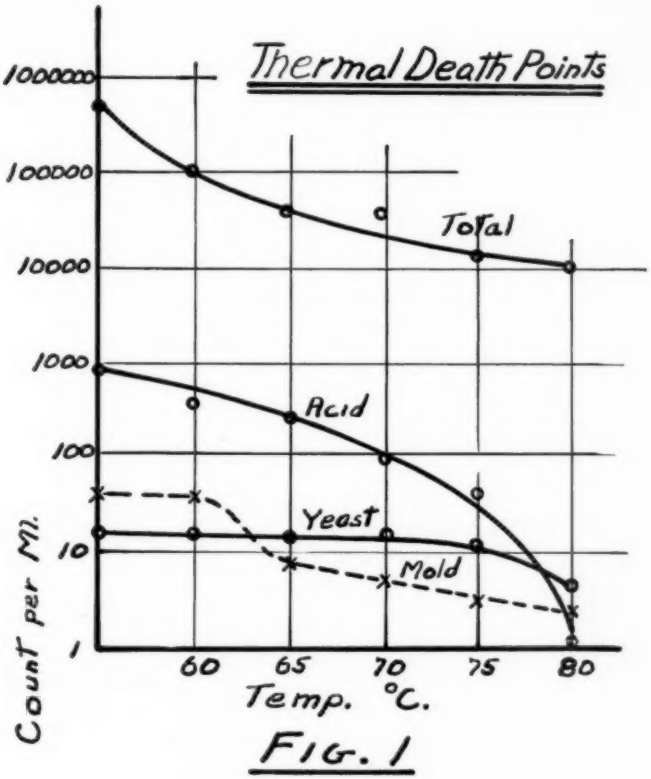

FIG. 1

Another factor equally as important is the latent period of the bacteria involved. It is well known, and we have verified on raw juice, that bacteria require a certain period of time after being transplanted to new surroundings before normal reproduction commences. In raw juice this latent period is about two hours during which time practically no increase in bacteria counts is noted. This latent period is of sufficient duration to allow the cossettes to pass thru the battery without an increase in count. The fact that we have a counter-current flow allows some increases in population. Dead spots and surfaces not continuously wiped by moving juices or pulp also allow increases in counts.

Figures 2, 3 and 4 are graphs of bacteria counts in raw juice, the juice from odd number diffusor cells, and battery supply water. Juice pH and temperature are also shown. The general shape of these curves is typical. Raw juice is highly contaminated due to contact with the cossettes. The counts decrease in the first several cells of the battery but in many cases show an increase at cell number thirteen due to aeration as the pulp is

lifted from the bottom to the top tier of cells. Quite often a decrease in pH was recorded at this point.

An important point which appears in these graphs, especially in Figure 3, is that of bacterial contamination of battery supply water. In Figure 3 this is most apparent. In several of the other graphs bacterial contamination of battery supply water infects the entire top tier of cells. Since at most mills battery supply temperatures of about 65° C. are common and it has been shown that this temperature is not high enough to effectively sterilize the water, we believe chlorination, bromination, or other treatment of battery supply water would be advantageous. A limited test at Carlton using 1.5 to 2.0 ppm residual chlorine seemed to assist in maintaining higher battery pH's. No bacteria counts were made.

Control of bacterial activity within the battery has been accomplished by either use of bactericides or higher temperatures. The use of bactericides such as formaldehyde or para-formaldehyde will maintain normal battery pH's if enough of the material is employed. It is unfortunate, however, that such materials as the aldehydes, chlorine, bromine, and halogenated phenols

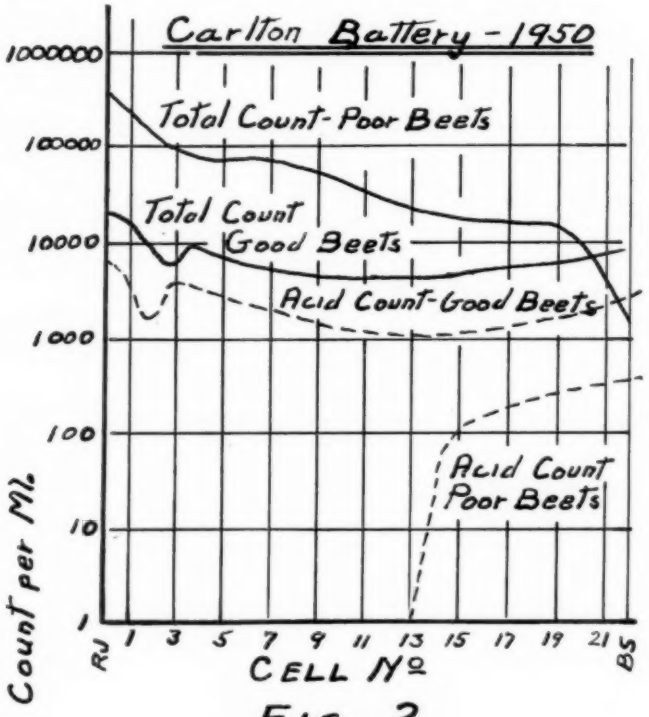

FIG. 2

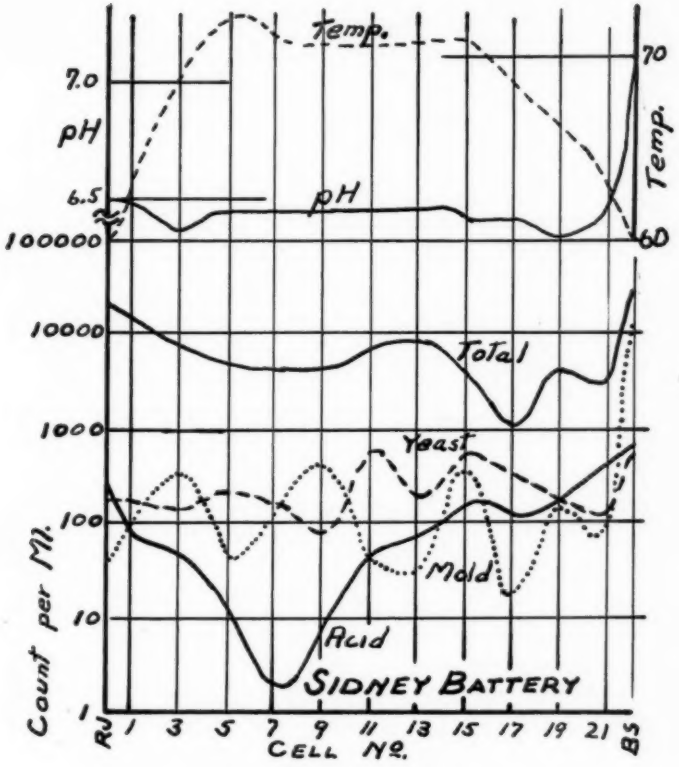

FIG. 3

quickly react with the organic matter in the pulp either chemically or by adsorption and become quite ineffective.

Increase of temperature through the battery is another means of controlling bacterial population. If the pulp is dried, temperatures on the tail end of the battery must not be too high or the pressability of the pulp is adversely affected. During the campaign just completed at Sidney, an

Table 1.

	No Dome Steam	Dome Steam
Average Dome Temperature	67	72
Maximum	67	77
Average Juice Temperature	62	66
Total Bacteria Count per ml.	464,000	63,750
Total Percent Kill		86.2%
Acid Bacteria Count per ml.	86,400	13,481
Acid Percent Kill		84.4%

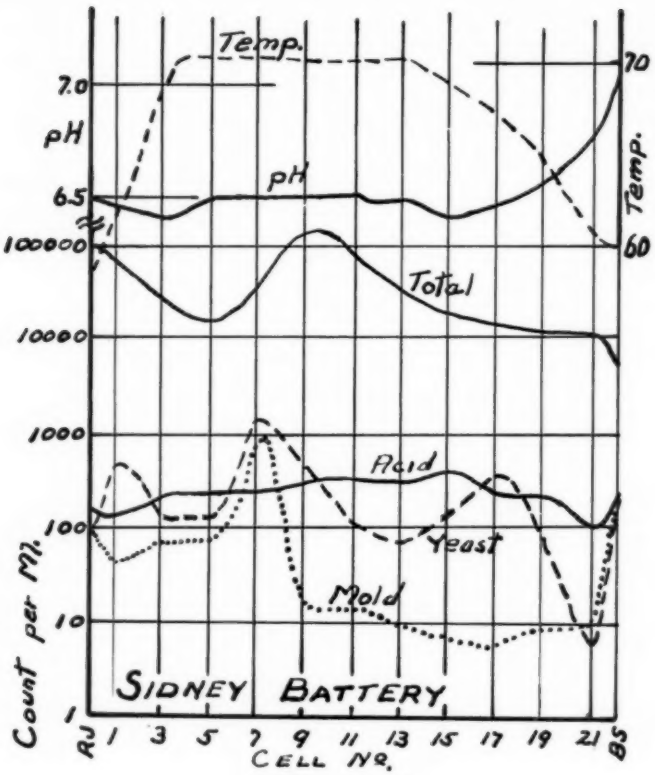

FIG. 4

attempt was made to increase dome temperatures to the thermal death point of 80° C. This was carried out by steaming individual domes in rotation against the flow of beets making a round of the battery on a four-hour cycle. Pan boiling steam was employed. Results are shown in Table 1.

Unfortunately it was not possible to introduce sufficient steam into the domes to reach the thermal death point; however, a maximum of 77° C. effected an 85 percent kill.

The last experiment on which we wish to report is the effect of a bactericide spray on the whole beets before slicing. Most of the bacteria entering the battery are contained on the surface of the beet rather than in the interior of it. It was reasoned that if the beets could be sprayed before slicing the bacteria could be killed and there would be less inactivation of bactericide due to reaction with the organic matter. Ten-day treatment periods were established, alternated with ten-day nontreatment intervals. Testing took place a day before the treatment was changed. Four sprays

were installed at the beet elevator discharge into the beet hopper, positioned so that the beets were sprayed while rolling and turning. This was an attempt to get as complete spraying as possible of the beet surface.

Roccal was employed as the bactericide. One hundred seventy-five gallons per day of 1,200 ppm (100% basis) solution were used. Results are shown in Table 2.

Table 2.

% Kill Total Bacteria	68%
% Kill Acid Bacteria	55%
% Kill Yeast	72%
% Kill Molds	80%
Daily cost at $8.00 gal. =	$3.36
Average pH during treatments	6.35
Average pH between treatments	6.15

The curves of batceria population throughout the battery are not included, but are typical of those previously given.

Conclusions

Due to the continuous nature of operations without hourly cleaning, bacteria problems in the continuous diffusor are much greater than those encountered in the conventional Roberts battery. Treatment of some type must be practiced to control bacteria populations or excessive corrosion and destruction of sugar will result.

pH of the juice is a good criterion of bacterial activity. Due to the latent period of the bacteria present, the most serious contamination arises from dead spots within the battery. The battery is, however, being continually reinfected from the beets at the head end and from battery supply water at the water end. Temperatures necessary to produce satisfactory kills are about 80° C. and periodic dome steaming on a regular cycle seems to be an entirely practical mode of control. In addition, dome steaming does not heat the juice excessively and so should not cause pulp pressing difficulties in the drier as does high juice temperature.

Roccal spraying of whole beets indicated significant kills, and additional work will be done evaluating the use of additional sprays. Possibly with the use of additional Roccal on beets, high intermittent dome temperatures, and treatment of battery supply water bacteria in the continuous diffusor can bc effectively controlled.

"Angola" Filters for Sugar Filtration[1]

HANS W. FORSTER[2]

The Enzinger "Angola" filters are vertical leaf type pressure filters and come as a logical sequence to other Enzinger filters, which have been well-known in the filtration field all over the world since 1890.

Enzinger leaf-type pressure filters are well established in many fields, including oil, beverage, gelatin, food, antibiotics and chemical industries.

The modifications made to the basic Enzinger leaf-type pressure filter in cooperation with men well acquainted with the problems of the sugar industry have produced a filter which is giving superior operating results in sugar plants.

Every plant is confronted with the same problem: that is, to effect the increase of operating efficiency, the decrease of maintenance cost, and the betterment of the final product. The Angola filter permits realization of all of these three items.

In the older type stationary filters, one major disadvantage is common: the comparatively slow and heavy physical work of cleaning the filters. Furthermore, the washing and periodic replacement of filter cloth, a large labor and maintenance item which tends to increase the overall filtration cost, is a disadvantage.

Rotary filters, with their involved mechanisms, require a rather high type of maintenance personnel to keep them in reliable operating condition.

By comparison, in the Angola filter, actual physical work of cleaning the filter consists merely of operating a number of valves. Conventional filter cloth is replaced by practically indestructible metal cloth which does not require frequent replacement. As the entire filter is of stationary design, including the sluicing device, all power-driven mechanisms and their costly maintenance are also eliminated.

In addition, the Angola filter affords:

1. Minimum outage between filtration runs, a factor which becomes particularly important, when due to other difficulties only short filtration runs are obtained and the filters must be cleaned quite frequently.
2. A marked decrease in filteraid consumption per pound of sugar filtered.
3. Elimination of possible contamination from materials of construction, as stainless steel and other highly corrosion-resistant materials are used in the construction of Angola filters.
4. The filter shells lend themselves readily to efficient installation, thus avoiding heat losses and affording better and more rapid filtration.
5. Filtration rates with Angola filters are far greater than with the older type filters and brilliancy of the filtrate shows a decided improvement.
6. Efficient sweetening-off operation represents a decided saving in water and subsequent evaporation and sugar losses.
7. The number of filters previously operated by two men can now readily be operated by one man. Furthermore, the washing of filter

[1] A test report on the filtration of sugar liquors.
[2] Enzinger Union Corporation.

cloths has been eliminated. The Angola filter also eliminates the high maintenance cost encountered on rotary type filters.

Description of Filter

The Angola filter as modified for the sugar industries is a 48 inch diameter leaf-type pressure filter containing 23 leaves spaced on 1⅞ inch centers, with an effective filtering area of 461 sq. ft. or 547 sq. ft. (depending upon leaf height) and available cake space of 28.9 and 34.2 cu. ft. respectively. The filter tank is designed in accordance with A.S.M.E. Code for unfired pressure vessels, Par. U-69. The filter leaves are constructed of stainless steel Type 304 or Type 316. The outer metal cloth is of fine mesh construction. The inner drainage member or backing screen is 4 x 4 x .080 inch wire wesh. The filter leaves are the key to good filtration and require the most careful attention in both design and fabrication. The filtrate channel is formed by the frame of each filter leaf and must be maintained free and clear. The screens have to be fabricated so that they will not protrude into this filtrate channel. The supporting tubular frame must be riveted tight under pressure to avoid any by passing of unfiltered liquor between the frames and the outer fine metal cloth. The corners of each leaf are formed to generous radii to permit maximum flow rates and thorough cleaning of each leaf. The three layers of screen are thus fastened together, followed by a rolling operation to insure tightness. No solder is used to effect this tightness between the outer frame and the fine metal cloth.

One of the most important modifications in the Angola sugar filter is the dual inlet connection of two 3-inch connections diametrically opposed. Each of these connections is equipped with a semi-circular channel baffle just inside the filter tank. The purpose of these baffles is to distribute the unfiltered liquor uniformly over all filter leaves, both from the top and from the bottom. With two inlet connections and two baffles, there are actually four unfiltered liquor distributing points. This arrangement permits rapid filling of the filter and thus avoids a decrease in liquor velocity. The turbulence of the liquor entering the filter keeps the filteraid in suspension, resulting in rapid and uniform precoating. Actual precoating time is approximately 5 minutes. This time was established during the last two crops at different sugar cane refineries.

Another modification of this filter is the provision of individual leaf outlets. The filtrate connection from each leaf is piped separately to the outside of the filter tank, terminating in 1 inch valves. From these valves the filtrate discharges into a common cooling trough. Samples may be taken from each individual outlet and tested for clarity and brilliancy. If for any reason the clarity of the filtrate is not satisfactory, this arrangement permits taking that leaf out of service. Also, when sweetening-off the filter, the flow of sweet water may be throttled in order to keep the amount of sweet water used to a minimum. This arrangement permits better control of the filter, especially when sugar liquors pretreated with vegetable carbon are to be filtered.

The entire filter is usually insulated with a 2 inch thick glass wool blanket to conserve the heat of the sugar liquor as much as possible. The

filter tank cover is arranged with a mechanical toggle lifting device and the cover swings on anti-friction bearings so that, after opening the clamp bolts around the periphery of the cover, the latter may be swung out of the way with a minimum of effort.

The stationary sluicing device is mounted in the top cover. This unit consists of a pipe header and a series of strategically located spray nozzles, arranged in such a way that the fan sprays of these nozzles not only form an uninterrupted spray pattern but also cover both sides of all filter leaves simultaneously. This system is designed to operate on 60 psi water pressure.

In addition to the top sluicing device, the Angola filter is equipped with two additional, but smaller, headers mounted in the tank bottom underneath the filter leaves. Each header is equipped with small nozzles pointing upwards into the spaces between the filter leaves. Both of these headers are connected to low pressure steam. In addition to supplementing the effect of the sluicing header, the steam headers may also be used for preheating the filter before filtration. The sluicing device is highly effective. Long range field tests showed that during one entire crop the average sluicing time per cycle was approximately 5 minutes.

The discharge of the spent cake is effected through a 6 inch valve at the bottom of the filter.

The inside of the carbon steel filter tank is coated with a baked on phenolic resin coating. Since all leaves are of stainless steel, there is only one metal in contact with the sugar liquor, and because of this no galvanic action can be expected, even with vegetable carbon for decolorization. Therefore, this coating prevents any possible corrosion of filter screens.

The precoating is generally made up with filtered liquor and about .14 lbs. of filteraid per each sq. ft. of filtering area. The size of the precoat tank should be approximately 100 gallons larger than the capacity of the filter tank and should be equipped with mechanical agitator rather than air agitator.

The filter is equipped with an overflow connection so that any accumulated air in the top of the filter tank may be bled off, thus insuring a completely filled tank at all times.

History

The first Angola filter for the sugar industry was designed and built in 1949 and installed for trial early December of the same year in the cane sugar refinery of the Fellsmere Sugar Producers Association, Fellsmere, Florida. The capacity of this refinery at that time was approximately 1,500 to 2,000 bags of 100 lbs. each of granulated sugar per 24 hours. One filter of 461 sq. ft. effective filtering area was sufficient for the filtration of all affined and treated sugar melt at 60° Brix. Since that time the Fellsmere plant increased its refining capacity and subsequently bought another Angola filter for the present crop. These filters were also installed during the past two years in refineries in Puerto Rico, Cuba, Venezuela and in the continental United States.

There are no Angola filters installed as yet in any beet sugar factories, but it is believed that this type of filter will be equally efficient and eco-

nomical in operation for the filtration of second carbonation juices or standard liquors in beet sugar factories as it has proved to be in cane sugar factories.

First Test Run at the Fellsmere Refinery

This factory used Sucre Blanc and vegetable carbon process. The first Angola filter was installed as shown in Figure 1, piping diagram. An existing plate and frame press was used as "check filter."

Sugar liquor was available in batches of 1,000 gallons each, and since the filter was capable of filtering this liquor at a much higher flow rate than the unfiltered liquor could be furnished during the first test, it was necessary to recirculate the filtered liquor between batches. Eventually, the individual leaf outlet cocks were adjusted so that the flow rate of the filter timed with the availability of the unfiltered liquor, and in that way the recirculating time was either eliminated completely or cut to a minimum.

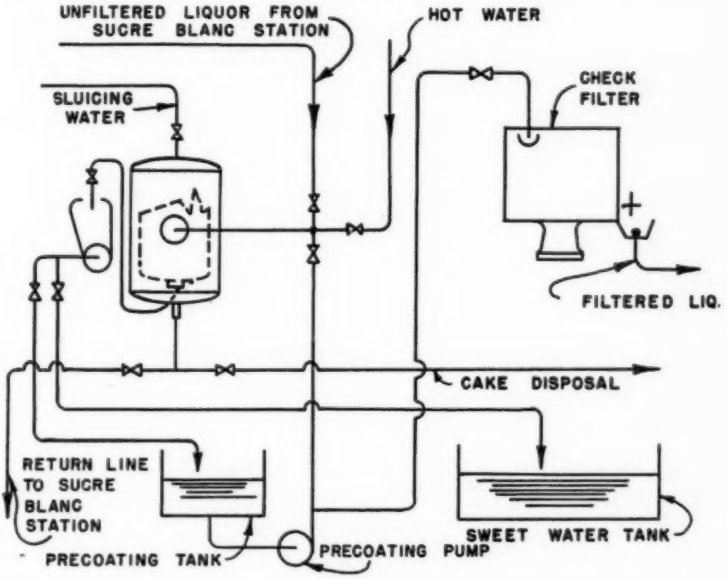

Figure 1.

During these tests the following data were recorded:

1. Number of 1,000 gallon tanks.
2. Time elapsed per tank.
3. Filter Pressure.
4. Strike (Type of raw sugar A or B).
5. Amount of filter-aid used.

The Brix ratings of the liquors were determined, and furnished by the plant chemist. All of these data were tabulated and plotted.

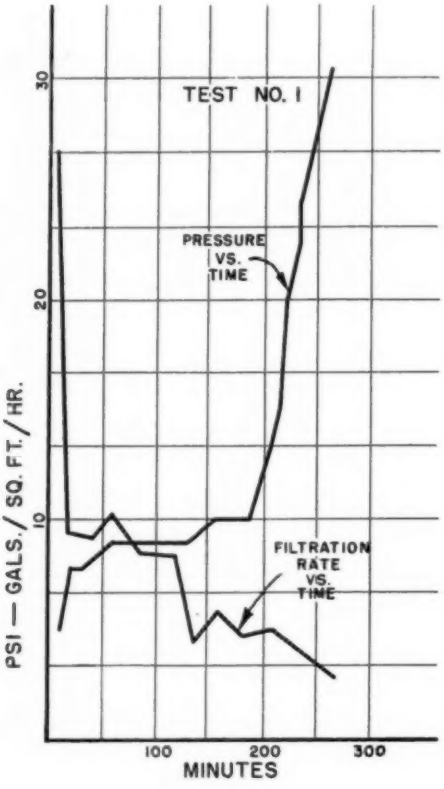

Figure 2.

Test No. 1.

For the initial filtration test the filter tank was filled from the precoating tank on the floor below. One hundred pounds of filter-aid was slurried up in the precoating sugar liquor tank by means of air agitation. This slurry was pumped through the filter with all valves open wide. The filtrate started to show clear after less than 5 minutes of precoating and filtration was started.

The first 1,000 gallons of sugar liquor were filtered in 5 minutes. The outlet cocks of the individual leaf outlets at that time were all wide open. The second batch, however, was not available until 10 minutes later, and in the interim the filtrated liquor was recirculated to maintain pressure on the filter leaves. A total of 14,000 gallons was pumped through this filter, and it is to be noted that the pressure on the filter increased sharply after batch 12. This was due to a disturbance in the clarification operation ahead of the sucre blanc station. This caused a far greater amount of mud of slimy calcium phosphate precipitation to come through with the unfiltered liquor than in normal operation.

Sweetening-off.—During the first test sweetening-off was not successful, due to operating difficulties outside of the filter.

Sluicing.—Steam was applied through the two steam headers in order to break up part of the spent filter cake, since the filter had been opened and a good part of the moisture from the spent filter cake had evaporated.

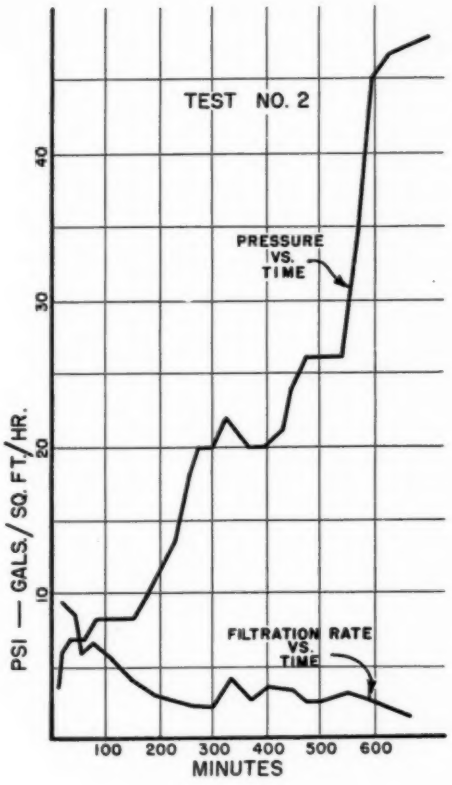

Figure 3.

The steam was kept on the filter for about 5 minutes, and caused the greater part of the filter cake to slough off. Then the sluicing-water pump was started and full pressure and volume of the sluicing pump applied to the sluicing device. Inspection showed no trace of filter-aid on any part of the filter.

The following are the results of **Test No. 1:**

A total of 14,000 gallons was filtered in 258.5 minutes; deducting 450 gallons of liquor, which was returned to the sucre blanc station at the end of this filtration run, a total of 13,550 gallons of sugar liquor, at an average Brix rating of 57°, was filtered; or an average flow rate of 52.4 GPM through the filter was obtained, which is equivalent to 6.68 gals./sq. ft./hr.

One hundred pounds of precoating and 115 pounds as subsequent additions to the unfiltered liquor, resulting in a filter-aid consumption of .00262 pounds of filter-aid per pound of sugar solids melted. On basis of syrup, the consumption was .0158 pounds of filter-aid per gallon of syrup. The graph of Test No. 1 shows clearly the rather slow increase of filtration pressure until the before-mentioned disturbance in the clarification operation took place, and at which time the pressure started to build up very rapidly.

The filtration rate curve showed a gradual decrease from the initial tremendous flow of somewhat over 25 gals./sq. ft./hr. to a final flow of 2.68 gals./sq. ft./hr., or an average flow rate of 6.68 gallons per sq. ft./hr.

Test No. 2.

During the second test run the filter was again precoated and showed clear filtrate after 5 minutes of operation. During this second test run an effort was made to increase the filter pressure in only very small increments,

and as a result it was possible to filter a total of 20,000 gallons. It would have been feasible to filter an additional amount, but the test had to terminate because of a scheduled refinery shut-down. Runs as high as 32,000 gallons on one precoat have since been made, with satisfactory flow rates.

Sweetening-off.—After the completion of the filtration cycle, the filter cake was sweetened-off by turning the hot water into the filter inlet in such a way as to maintain the same pressure as existed during the final phase of the test run. The discharge from the filter was permitted to run into the filtered liquor tank, and the Baume' rating of the liquor during the sweetening-off cycle was checked continuously until a rating of approximately 20° Be' was obtained.

After the filtrate was brought down to 20° Be', it was turned into the sweet water tank and all of the individual discharge cocks were throttled as far as possible in order to keep the amount of sweet water used to a minimum. It was also found that the time of contact of the sweetening-off water with the filter cake is far more influential than a high rate of flow. A leeching effect of the hot water is desirable, in order to obtain thorough sweetening-off of the filter cake. A total of 660 gallons of sweet water was used, or the equivalent 1.47 of the volume of the filter.

It is to be noted that, with the exception of the sudden increase in the last two batches, the filter pressure increased slowly, in comparatively even increments. The filtration rate (apparently as a direct result of slow increase in filtration pressure during the run) diminishes very slowly and showed an overall average of 3.87 gals./sq. ft./hr. or a flow rate through the filter of 30.3 GPM.

It is to be seen that the decrease in filtration rate over that shown in Test No. 1 is directly due to the effort of keeping the filter operating at the rate at which the batches of unfiltered liquor became available.

During the second test a total of 300 pounds of filter-aid was used, which is equivalent to .00252 pounds of filter-aid per pound of sugar solids melted, or .0154 pounds of filter-aid per gallon of liquor.

As during the first test the filter was again opened prior to sluicing off the cake, and samples of this cake were taken. Of course, it is obvious that by the time the filter was closed again a good part of the moisture had evaporated and caused the cake to be rather dry and sticky. Inspection showed that a cake thickness of approximately ⅜ inch had deposited. A precoating of approximately 1/16 inch thick was quite noticeable. Samples of this cake showed a .604 polarization, which is equivalent to a negligible amount of sugar left in the spent cake. The filter was again closed and steam turned on. The greater part of the cake sloughed off immediately and after approximately 5 minutes the sluicing water was turned on; the filter was found to be absolutely clean after 6 minutes of water sluicing.

These tests and other field checks have proved that the Diatomite filter is entirely practical for the sugar industry.

Summary

All filters do not require the individual leaf control cocks, and such filters are equipped with a common manifold outlet for all leaves; these filters are identical in all other respects to the one described earlier. The filter leaves for either filter with or without individual cocks are of the same design and construction.

The automatic sluicing, which is essential when continuous operation is involved, can be done away with for batch operation. In this case, the filter is equipped with a chain-type hold-down bar. Removing this bar allows the filter leaves to tilt toward the fixed center leaf, thus exposing a large surface of the leaf for convenient manual sluicing of the spent filter cake, without removing the leaves from the filter. The tilting of the leaves does not cause the leaf outlet nozzles to disengage from their seats in the outlet manifold. The fact that the leaves do not have to be removed from the filter prolongs their life, as they are thus not subjected to mechanical damage.

Chemical Aids to Carbonation Mud Settling and Filtration

SOMERS MOORE[1]

In recent years, many factories have greatly increased beet slicing capacity by the introduction of continuous diffusers, and have consequently shifted the rate-limiting process to a later stage. Even though the sugar content of the cossettes may have dropped, so that little, if any, more sugar is being produced, a much greater tonnage of juice must be handled in carbonation and evaporation.

This situation developed in one of our plants until a muddy Dorr overflow with excessive mud to the second carbonation filters became the limiting factor in house capacity. At the same time, constant efforts were

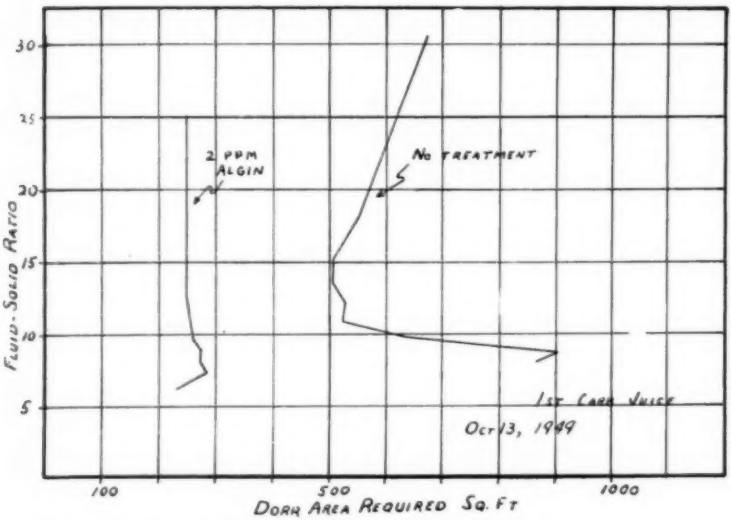

Figure 1. Typical settling test data for a Steffen house.

being made to improve sugar quality. According to the work of Skaar and McGinnis (1)[2] we consider it axiomatic that color reduction is favored by high alkalinities in first carbonation, but that alkalinities approaching the optimum inhibit mud settling in the Dorr thickener.

It had been noted by Losee (2) that agar was useful in accelerating the filtration of $CaSO_4$ slimes. No noticeable effect by agar on first carbonation juice could be noted. However, in the fall of 1949 and after, a number of other gummy materials were discovered which often effect a

[1] Chief Chemist, Spreckels Sugar Co., Spreckels, Calif.
[2] Numbers in parentheses refer to literature cited.

radical improvement in first carbonation settling rates. The following materials have all proved more or less useful:

Algin (sodium alginate)
Gum arabic
Carboxymethyl cellulose
Irish moss gum
Gum Karaya
Kelcoloid HV[3] (the propylene glycol ester of alginic acid)

An investigation of the usefulness of these compounds was made by the settling test of Coe and Clenenger (3) as modified and described for carbonation work by McGinnis (4). I am indebted to Dr. McGinnis for the settling test data which follows. In most of our tests we used algin, Kelgum.[4]. Alginic acid is a polymannuronic acid derived from seaweed.

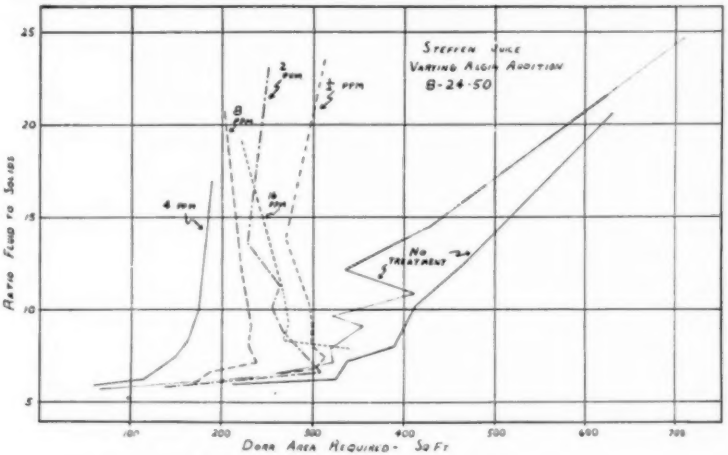

Figure 2. The effect of Algin addition.

Figure 1 shows typical settling test data for Steffen house juice. The ordinate is the fluid-solid ratio at various stages of thickening, the upper portion representing the thin Dorr feed, the bottom the thickened sludge discharge. The abscissa is the settling rate expressed as the area required to settle the juice from a nominal factory. The algin reduced the area required from 900 to 200 square feet. Figure 2 shows the effect of varying algin addition. This shows a rather clear optimum at 4 ppm., but many tests have shown the optimum to be variable and not too sharp, so we ordinarily compromise at 2 ppm. algin on juice.

The concentration of algin in the solution fed to the Dorr is critical. It was found that a solution even as concentrated as 1 percent does not work at all, while 0.1 percent is convenient and most effective. We use a 0.1 percent solution of algin in water. Algin dissolves rather slowly, so in

[3] Trade name of the Kelco Company, Los Angeles, Calif.
[4] Trade name of the Kelco Company, Los Angeles, Calif., for their brand of sodium alginate.

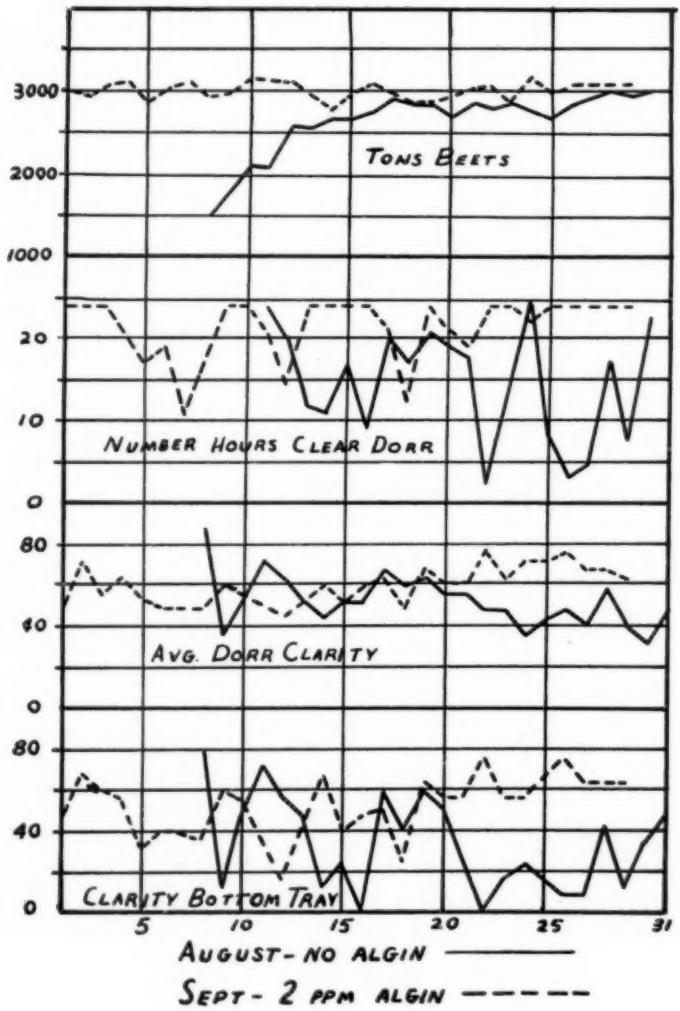

Figure 3. The effect of 2 ppm. algin addition in a Steffen house.

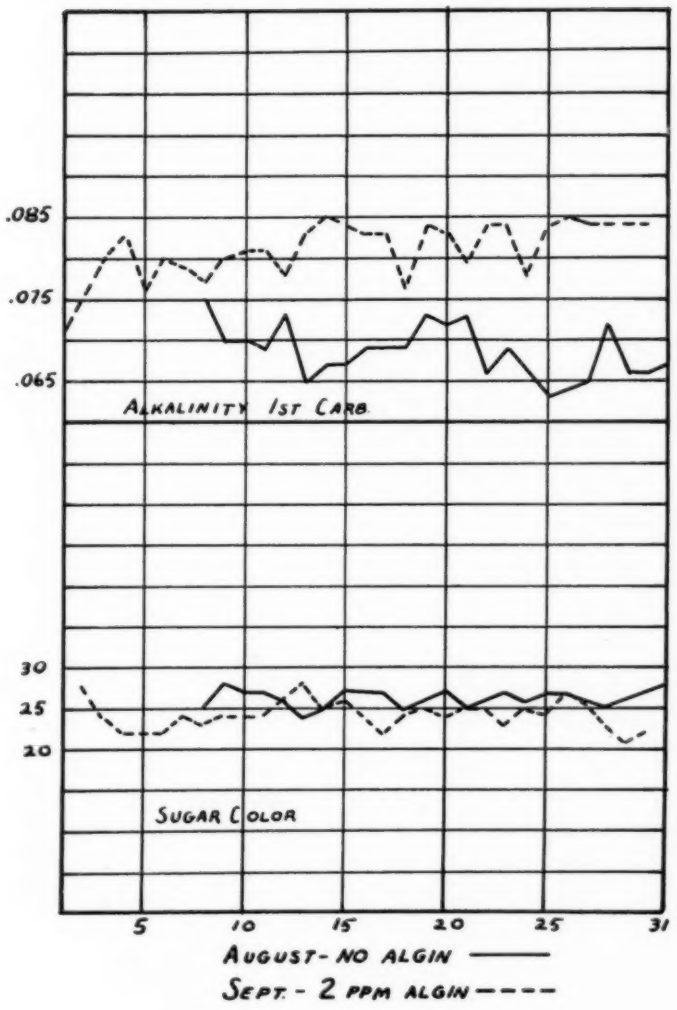

Figure 4. Continuation of Figure 3.

the factory we use two tanks each of 4 hours capacity, one stirring and dissolving while the other is in use. In very hard water an insoluble calcium alginate inhibits solution, and a polyphosphate sequestrant may be desirable.

Figures 3 and 4 show actual operating results for a Steffen factory for the first two months of the 1950 campaign. 2 ppm. algin on juice was added in 0.1 percent solution to the pipe line from first carbonation to the Dorr thickener. The comparison is not very useful until the slice in August reached a fairly high level, but it is clear that in September with algin addi-

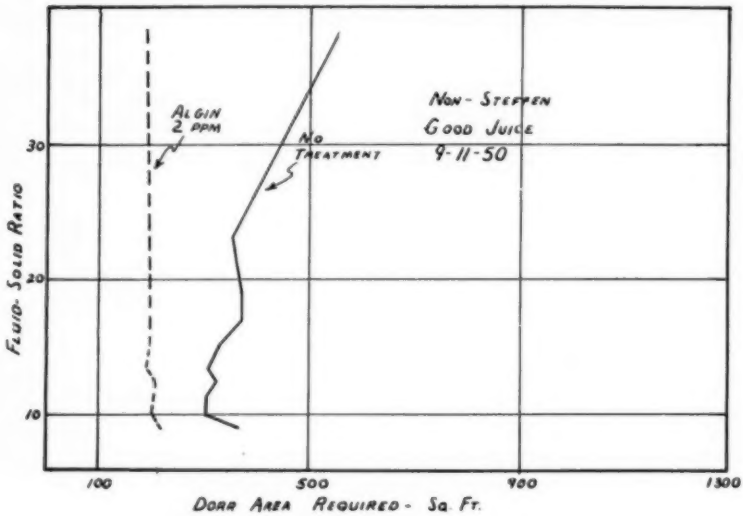

Figure 5. Settling tests at a non-Steffen factory.

tion we sliced more beets at a higher alkalinity, with a much clearer Dorr. Subsequent comparative tests in this factory were difficult to arrange because the factory operating staff was convinced of the efficiency of the algin addition, and because, whenever the algin was discontinued, the Dorr ran muddy in a few hours. Good results were readily obtained at our non-Steffen factory (Figure 5) and routine use of algin at these two factories has continued.

There is a property of juice which we may call algin susceptibility. The juices in the settling curves shown previously have all responded very well at all fluid-solid ratios. Figures 6-9 show a series of tests in which the effect of algin is successively less and is finally harmful at all ratios. Figure 6 shows a juice with a top-rate determining curve which was helped by algin, but shows a toe developing at a ratio of about 7. This juice was at .066 alkalinity. In Figure 7 we have about the same effect at .064 alkalinity. However, in Figure 8 we have a very poor juice at the same factory at .086

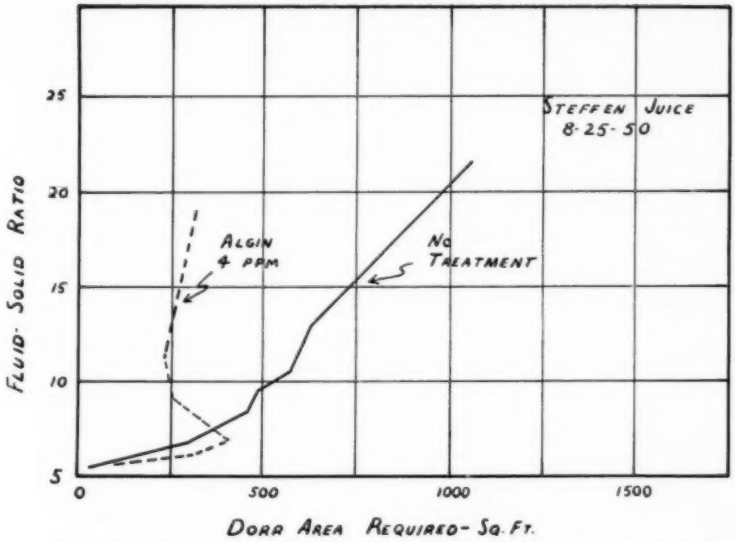

Figure 6. Although the algin is still effective, a "toe" is developing in the settling rate curve, at the level of the thicker slurry.

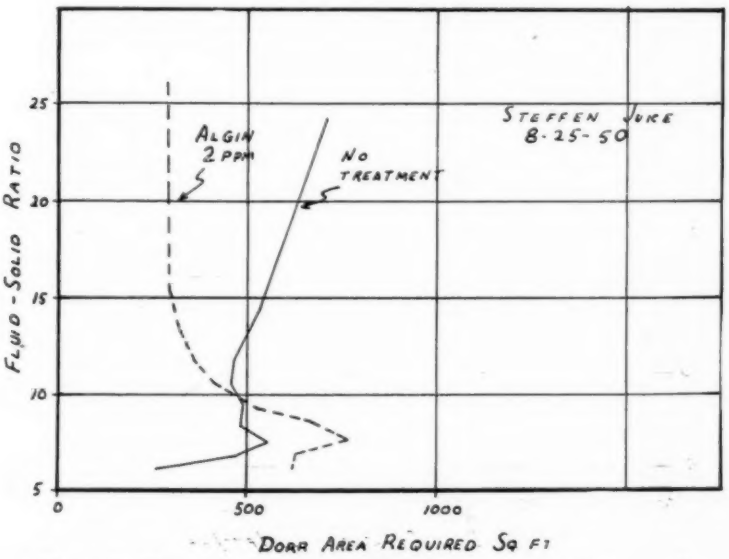

Figure 7. The "toe" is now controlling.

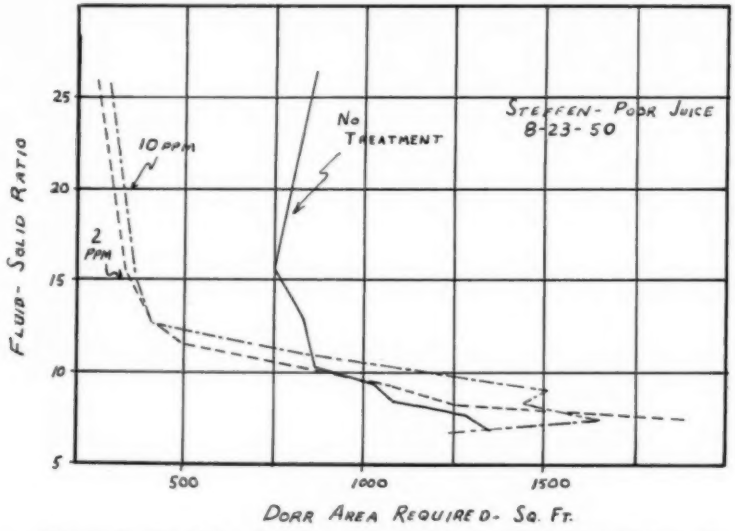

Figure 8. On this refractory juice, algin is definitely harmful to the settling rate of the thick slurry.

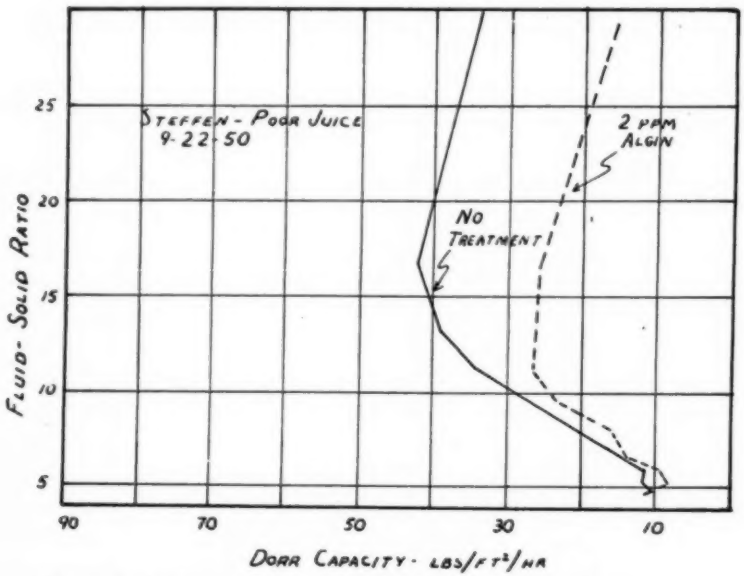

Figure 9. In this case, algin was harmful in all proportions.

alkalinity in which the algin was actually harmful on the thicker juice. We can make two generalizations about algin susceptibility:

1. Algin almost always helps the settling of the thin slurry, but as the susceptibility of the juice decreases, trouble develops with the thicker slurry, the bottom of the settling rate curves.

2. Juices which are naturally the best settling are most susceptible to the action of algin.

Figure 9 shows an extremely refractory juice in which algin was harmful in all proportions. At this Steffen house, the use of algin has never been successful in the factory, and only very rarely on laboratory samples. Settling and filtration difficulties are characteristic of this house, and it is here where effective algin treatment would be most desirable that the algin susceptibility is lowest.

Algin treatment, then, is indicated when carbonation is normal and the trouble is a physically overloaded Dorr. Algin will not be useful and may be harmful if the trouble is poor carbonation. Generally, predefecated juices are slow settling juices and algin will not be useful. However, algin will work well with batch carbonated juices if they are carbonated to a good break.

The settling rates in the curve are based on the "break" line. There is usually some residual haze of fines in the supernatant liquid. Algin treatment will reduce the suspended solids in the overflow to ½ to ⅓ the original value. Also algin frequently improves mud filtration rates very markedly, due to the agglomerated character of the floc.

Sodium alginate in solution dissociates into sodium ions and a multivalent colloidal negative ion. Since the carbonation floc particles are positive, it is believed that weak electrostatic bonding is responsible for coagulation.

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The "Floc" Problem in Beet Sugar

F. M. Sabine[1]

In view of the fact that Ed Maudru, general chemist for Holly Sugar Corporation, and I have been assigned as moderators for the floc problem in white sugar, I believe it would be well to trace briefly the history of this new subject in our operations before we begin a general discussion on this subject. Since Mr. Maudru, as general chemist, would be primarily concerned with the chemical phases of this problem, and I with operating problems, I will to the extent possible limit my remarks in connection with this subject to the operating phases.

History

During the course of the past several years several complaints with respect to the use of beet sugar have been brought to our attention by the Seven-Up Company of St. Louis, Missouri, through Dr. B. C. Cole, who is in charge of the product department. This department is actually the quality control laboratory for the bottlers who hold franchises to put up this product. Periodic samples are furnished this laboratory where they are tested for taste, uniformity and quality. In making their tests they have at times found off-quality in their product, which was ascribed to the use of beet sugar. The following factors they claim have given the Seven-Up Company trouble with beet sugar were described as:

1. "Delayed action" floc.
2. "Fertilizer" odor.
3. "Metallic" taste.
4. Foam at the filters and in the syrup.

These descriptions are based on the physical tests of odor and flavor made by personnel trained and qualified for this type of work. The "delayed action floc" occurs most consistently in Seven-Up through the use of beet sugar at the pH of the formula used, and from their standpoint is the most important objection to the use of beet sugar.

Since the so-called floc test is the one under discussion my remarks will be limited to this subject.

In 1950 this was called to our attention before we had any knowledge of their problem and Dr. G. A. Vacha and I visited the St. Louis office of the Seven-Up Company. Efforts in the factory laboratory to reproduce this "floc" with citric acid and sugar solutions were not too successful. In fact, little "floc" formation resulted and yeast and mold growth occurred before a "floc." Apparently the Western Beet Sugar Producers' Committee through R. S. Gaddie furnished the various companies with the so-called "Coca-Cola Floc Test" which is used by that company. The test will be described later merely as a matter of information.

In July, 1951, Dr. Cole contacted representatives of the sugar com- regarding a new "floc" test which they developed and which requires less than 24 hours for a "floc" to form, although the 24-hour period is recommended for evaluating purposes. The test briefly is to heat a 10 percent sugar solution at 100° C.-115° C. for one hour after having been adjusted to an approximate pH of 2.70 with hydrochloric acid. Tests on heating at the boiling temperature for one hour apparently work satisfactorily, but

[1] General Superintendent, American Crystal Sugar Company.

not much experience has been had with tests at lower temperatures than 100° C., which normally requires an autoclave. The details of this test were tabulated and Mr. Gaddie of Utah-Idaho Sugar Company was appointed to work out the specifications for the racks (2½ inch diameter holes) and the globes to be used for such tests in order that these tests would be made on a uniform basis.

The other "floc" tests which were previously used are:

Coca-Cola Floc Test: A 50-55.0 BX sugar solution is adjusted to 1.50 pH to 1.60 pH with phosphoric acid and allowed to stand for 10 days to check "floc" development. The sample is one gallon and placed in a one-gallon jug for the 10-day period. The jugs should be sterile.

Holly Sugar Corporation: 40 gms. sugar, 30 ml. H_2O, ½ gm. citric acid allowed to stand for five days (no heating). Containers should be sterile.

Great Western (Also used by Utah-Idaho): 10 gms. sugar, 25 ml. H_20, 2½ gms. citric acid/100 ml. using 1 ml. acid solution for the test and heating to 80° C.-90° C. for one hour. Remove and take reading after one hour.

Seven-Up Test:

Beet Sugar Floc Test

(On One Gallon Basis and One Quart Basis)

1. Use 400 grams sugar (approx. 10 percent solution) to one gallon. Use 100 grams sugar for 1,000 cc. or one quart. (1,000 ml. Florence flask).
2. Add distilled water to volume (neck of bottle or flask).
3. Add ¼ cc. concentrated HCL (pH approximately 2.70) to one gallon solution. Add 4 cc. N HCL for 1,000 cc. or one quart.
4. Heat to 100° C. for one hour.
5. Observe after 24 hours over light beam.
6. Report results as below:

0 — No definite general floc.
\+ — Barely visible, very fine, general floc.
++ — Very definite but fine pin-point type floc.
+++ — Larger (1/64 inch) but pin-point (not loose) floc.
++++ — Large, loose snowflake-type floc with clearing of solution.

Notes: Insufficient experience has been had with respect to these gradings as compared to floc formation in bottled Seven-Up. Did not anticipate difficulty with "0" or "+." "++" and over doubtful for Seven-Up.

This test apparently exaggerates the trace compound, or trace compounds which "floc" out under the conditions of the test. However, it is an impurity which definitely influences the use of our sugar for specific purposes since cane sugar while containing such tract impurities does not form a floc under these conditions. The Seven-Up Company is next to Coca-Cola in national distribution, and a large number of plants are located in areas where the bottlers are receptive to beet sugar and want to use it. When trouble occurs, however, with a "floc" formation in their product they receive complaints, and since the product quality is carefully checked by the St. Louis laboratory, they recommend switching to cane sugar, which they claim clears up this trouble. The Seven-Up Company through Dr. Cole, however, has been cooperative in trying to work out these problems with the industry.

The companies working on this problem have the following observations to make from their experience:

1. The floc forms in all sugar end products starting with thick juice.
2. High pan purities result in low floc formation, on the basis of tests on all pans at Carlton during the 1950 campaign.
3. The floc tendency increases as deteriorated storage beets are worked.
4. High carbon addition 0.5 pound to 1.5 pound per ton of beets apparently reduces or eliminates the floc as determined by the Coca-Cola floc test. There is not enough experience with the Seven-Up test to note the carbon influence, but apparently the carbon effect is not so noticeable.

In studying this problem from an operating standpoint, numerous floc tests were made prior to and during the 1951 campaign period, and to our surprise and satisfaction very few if any of the samples tested exhibited any tendency to form a floc based on the tests used. Except in infrequent cases, the floc tests did not indicate more than a "+." While many of the floc tests made on the 1950 production did indicate at some plants a condition of higher floc properties in the sugar, there was a possible explanation that any low amounts found in 1951 were due to the higher quality of beets processed. In southern California the purity of the beets averaged approximately 0.5 percent higher than in 1950. At Clarksburg, California, the purities were 1.2 percent higher, and for the 1951 campaign as a whole, the average purity of the beets sliced was .61 percent higher than in 1950. In the Red River Valley the average purity was slightly over 2.5 percent higher than in 1950.

If the substance or substances producing floc in beet sugar depended on the concentration in the beet, then there is some logical explanation for the lower floc encountered in the 1951 production. Some preliminary work indicated that there was a possibility of absorbing this floc-producing substance by treating solutions of granulated sugar with de-colorizing carbon or compounds such as Adsorbol or a mixture of the two. The cost of such treatments on granulated sugar after it is produced is prohibitive and if sufficient quantities of materials outlined were applied on a factory scale any amounts which would probably be required would raise the production costs higher than justified for the known potential market for floc-free sugar. If used in the bottler's plant there would be the absorption of desirable flavor characteristics.

There is a serious question in our minds also that such treatment would be entirely effective on sugar end liquors, since, for example, there are non-sugars for which these materials would have selective absorption properties which would not confine themselves to whatever substances causes the floc. A number of years ago J. C. Keane, while working with the United States Department of Agriculture, did some work which indicated that at least certain mineral constituents were crystallized out at the end of the boiling operations or that their solubility was such at that concentration that they adhered to or were absorbed on the outer surfaces of the sugar crystal and that increased washing resulted in a lower ash content of sugar produced.

During our 1951 operations we, therefore, concentrated as much as possible on good centrifugal work and, while all of you are familiar with

centrifugal operations, experience has indicated that in plant supervision the following points should be checked into carefully and followed up by frequent and careful supervision:

1. All centrifugals should be checked to be certain that mechanical operation is good and that the machines operate at full speed.
2. Individual machine cycles should be carefully adjusted for the grain size of the sugar boiled.
3. In prewashing the sugar, the water should go on as soon as possible before the machine gets up speed and the second washing should also go on at the proper time and preferably before all the syrup leaves the sugar wall.
4. Wash water temperature and pressure should be carefully regulated in order to provide sufficient water for proper washing. The quantity of such water delivered per machine also should be carefully checked.
5. Nozzle adjustments should be carefully checked and maintained in order that uniform washing is always obtained.

In view of the fact that in 1951 most of the sugar end products, including intermediate sugar, exhibited floc-forming tendencies when subjected to the so-called Seven-Up test, the indications were that with the substances being present in intermediate products prior to standard granulated it might still be found in the final sugar if centrifugal operations on the white, intermediate and low raw sides were not carried on as efficiently as possible. There still remains the possibility, however, that the concentration of floc-forming substance in the sugar end products in 1951, due to the higher purity of the beets, was lower than would normally crystallize or become insoluble at the density of pans boiled.

In any event, the result of 1951 operations, in general terms from our company's experience, has been that the floc problem has not existed to the extent that it did in 1950. As previously stated, there is evidence from past experience that good centrifugal operations and washing operations always result in a better final product and, while there is a limit to the quantity of wash water which can be used in centrifugal operations, it is felt that proper attention to such operating details under all conditions will result in improvement in sugar quality, which we are all striving for, and should in turn result in a sugar relatively "floc" free.

In view of the fact that the bottling industry is the second largest industrial user of sugar, we should do everything possible, within reasonable economic limits, to furnish a sugar which will not result in complaints from the trade, especially having in mind that when complaints with respect to the "floc" problem result it is claimed to have been eliminated by using high quality cane sugar. This does not necessarily mean, however, that all cane sugars are free from this "floc" problem.

In view of the fact that a discussion of this problem has not given everyone an opportunity to observe the tests such as we had the opportunity to do in St. Louis, we have prepared floc tests representing the "+," "++" and "++++" floc test in sugar which were furnished by the Seven-Up people in St. Louis, and which were kindly prepared by Mr. Gaddie of the Utah-Idaho Sugar Company. He has also furnished us with the facilities for viewing the occurrence of this material in the sugars furnished.

"Floc" in White Sugar

J. E. MAUDRU[1]

It has been noted for a number of years that certain sugars, both cane and beet, produce, in low pH soft drinks, a floc-like material, white in color, which in the case of beet sugar settles on the shoulders of the bottle of beverage. The objection to this material, even though tasteless, is that the consumer thinks it is foreign matter and, therefore, objects to it. The composition of the floc is not known exactly. It is believed, however, that it is of colloidal nature whose iso-electric point is near the pH of the beverage. Investigations are presently being conducted by several agencies to determine the composition of the floc.

The 1951 campaign is the first year that Holly Sugar Corporation has made use of the floc test as a routine test. The procedure used follows very closely that proposed by Dr. Cole of the Seven-Up Company. A 500-ml. Florence flask is used as a container. Fifty grams of sugar are dissolved in distilled water and made to volume in the flask. One ml $\pm$ of hydrochloric acid diluted one to sixteen is added. (The pH of the sugar solution is to be 2.70). The flask is heated to 100° C. for one hour and examination is made after twenty-four hours standing. Results are reported as follows:

0 = No definite general floc.
\+ = Barely visible, very fine general floc.
++ = Very definite but fine pin point type floc.
+++ = Larger (1/64 inch) but pin point (not loose) floc.
++++ = Large loose snowflake-type floc with clearing of solution.

In all sugars tested a haziness became apparent. This, however, is not considered as floc. A great deal of confusion existed at first on grading the floc, in that the different laboratories could not check results. All floc tests for the entire company are now run at one laboratory. The light used for grading was a Quebec Colony Counter, which provided very strong illumination laterally through the flask.

During the spring campaigns the occurrence of floc in the sugar correlated very nicely with pan purity. Sugar from pans of 91.4 purity were floc positive, while sugar from 92.5 purity pans showed no floc. In fact, predictions were made on which strikes would be floc positive and, in almost all cases, these predictions proved to be correct after floc had been determined. During the fall campaign the floc test was made on all bottlers' sugar strikes. Floc rejection was very slight, since all the sugars produced as bottlers' sugars were treated with a .3 pound decolorizing carbon per bag of sugar, and the white pan purity was maintained at as high a point as possible.

At the present time under the auspices of Sugar Information, Inc., representatives of both the bottling industry and the sugar manufacturers are setting up overall standards for bottlers' sugar. Although the standards at the present writing have not yet been formulated, it is our understanding that they will include ash, color and floc. We feel that, in order to meet any very stringent standards on ash and color, which probably can only be accomplished by high pan purity, use of carbon and superior machine work, the floc problem will be automatically taken care of and will cause sugar manufacturers very little trouble.

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[1] General Chemist, Holly Sugar Corporation.

Mud and Trash Handling

R. M. DANIELS[1]

Upon the advent of beet loaders in the early forties the processors' difficulties, as far as handling beets were concerned, mounted by leaps and bounds. Such loaders not only picked up the beets but rocks, hard clods and trash as well. A-frames accomplished some good when properly used but usually the frame was not any wider than the loading frame and clods and rocks were picked up from the sides. Experience with these loaders clearly demonstrated the fact that **once beets were lifted out of the ground they should never be put back on the ground.**

Clods from heavy soils were not screened out by receiving equipment and were flumed with the beets. In many locations these clods, absorbing some water and traveling in the flumes, became balls ranging in size from ½ inch to 12 inches in diameter. Clods which broke down filled the flumes with mud and the customary manner of fluming beets became obsolete.

To overcome these difficulties various methods were used from plows to jets in the bottoms of the flumes and armies of men with forks and pieces of pipe lined the flumes. Still the slicing capacities suffered both due to our inability to get sufficient beets into the beet hoppers and poor cuttings caused by mud, rocks and trash in the cutters. It was obvious that our beet handling equipment was entirely inadequate and major changes were necessary.

In 1945 at the Hardin, Montana, factory a continuous rock catcher was installed in place of the conventional Franklin rock catcher and a flume-flushing system developed. The rock catcher consisted of slat buckets on conveyor chains continuously passing under a section of the flume. These buckets were carried up over the flume and discharged on a belt carrying the mud balls and rocks outside the factory. A 10 inch header was run to the sheds and flumes supplying water to jets and a flume-flushing system. A 1,600 gpm. pump having a 200 foot head driven by a 100 HP motor supplied the water under high pressure.

After the 1945 campaign we found that such measures still did not solve our problems. We could not get enough beets into the factory to keep up slicing capacity. It was clear that we had to redesign the entire beet sheds and flumes, which was done the following year. Steel sheds were built having a 3 percent grade in the steel flumes and an entire rearrangement of flushing system made with jets in the shed flumes, header and flumes to the factory. Fire hose connections were placed at strategic locations where stoppage might occur. The ½ inch jets placed in the flumes on 18 inch centers at 45° angles looking down stream were very effective and we found that steel flumes lend themselves to much easier cleaning than cement ones.

The rocks and mud balls mentioned above were conveyed outside of the factory where they were handled with a crane and dump truck. In a short time great mounds of this material accumulate and in the last campaign we had as many as 3,750 tons piled in the yard waiting for removal with dump trucks.

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[1] General Superintendent, Holly Sugar Corporation.

Figure 1.—Mud and mud balls being discharged from continuous rock catcher.

Figure 2.—Beets and mud as flumed from beet shed.

Figure 3.—Beets and mud being conveyed to sheds.

Figure 4.—Beets and mud in beet sheds.

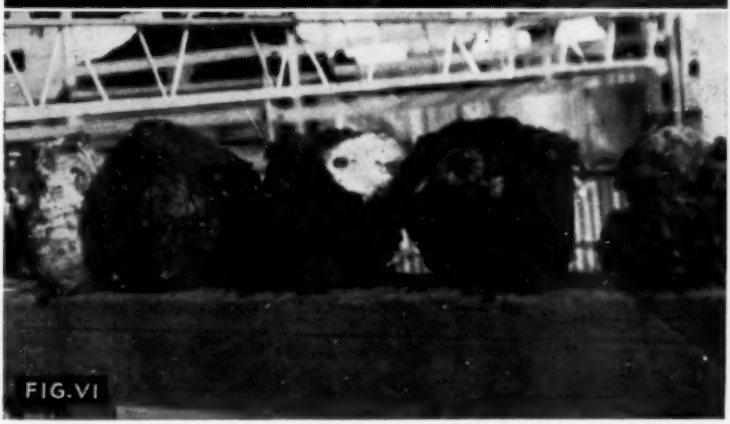

Figure 5.—Some of the accumulation of rock catcher discharge.

Figure 6.—Some individual beets as received, covered with frozen mud.

Typical tares in this area are as follows: 20 percent avg. tare for an entire district with some dumps running as high as 25 percent and individual loads as high as 70 percent. Some growers have averaged from 37 percent to 46 percent for their entire crop.

Trash consisting of grass and roots not removed at the receiving station aggravates the situation as well, but other than to install additional trash catchers of the conventional design we have done nothing new except close in the sprocket drive end of the rake drag with either perforated metal

or sheet steel to hold the trash hooks in a horizontal position as they travel up over the head end of the trash catcher. This has been very effective in retaining trash on the hooks after it leaves the flume stream.

During the last campaign conditions in Montana seemed to get worse and we now find additional grade necessary in the flumes from the sheds and wet hopper to eliminate extra labor and keep the factory operating to capacity. Flumes with 4 to 6 percent grade will probably be necessary to accomplish this.

In the Imperial Valley where soil depths are up to 1,200 feet in thickness no rocks exist but considerable loss in slicing time was experienced due to rocks and tramp iron brought in with car beets and we are installing a conventional rock catcher this year.

Beets harvested with harvesters presented another problem in the Imperial Valley as large tonnages of beets are delivered with 2 inch to 4 inch leaf stems still on the beet. These stems break off and are in sufficient quantities together with leaves and other trash to plug an ordinary trash drag although high pressure jets are used to keep the bars clean. Beet leaf stems and other trash accumulated in the sludge collector at the Carlton plant to the extent that it was necessary to remove this floating mass with a crane. When this mass decomposed complaints were received from residents in the neighborhood. This year we are planning to use a vibrating screen as a secondary screen recovering this trash as a stock feed. The bars in the trash drag assembly will be changed to provide a half inch spacing, thereby making them more clog free, and the trash getting thru these openings will be screened out by the secondary screen. Proper equipment will be installed to load the trash from the secondary screen into trucks moving to the feed lots.

If it is impractical or impossible to clean up beets in the fields and the receiving equipment is inadequate to remove the mud, trash and dirt from the beets, the job has to be accomplished at the factories if we expect to maintain rated slicing capacity.

The Steffen Process—Practical Application of Basic Principles

AVERY A. CLARK[1]

In principle, there have been no new developments in the Steffen process over the last fifty years. In Claasen's "Beet Sugar Manufacture," the first edition of which was published in 1901, he says, in effect, "Molasses is mixed with water to 14° Brix or less and cooled down to the temperature of the cooling water. Powdered lime is introduced and mixed uniformly with this liquid, the recovery of sugar is best at a temperature of not over 10°-12° Centigrade." He further states, "Particular stress is laid upon pulverizing the lime because the amount used is in proportion to the fineness of the powder," and again "the wash water must be as cold as possible."

For more clarity and to give weight to some of the practical features of operation which experience has shown to be quite important, the statement of these principles might be expanded somewhat as follows:

1. Lime powder should be as high in CaO as possible, at least 86 percent, and should contain no appreciable amount of either over-burned or under-burned material and should be ground to a fineness of 1 percent plus 200 mesh or less.

2. The solution-for-cooler should be at least 6 percent sugar by polarization. Uniformity of the solution, both as to sugar content and volume, is essential.

3. Weights of lime in proportion to sugar in the cooler solution must be accurate within narrow limits.

4. Cooler temperature before, during and after lime addition should be held as low as the temperature of the cooling water will allow.

5. Increased cooler solution temperature, whether from heating molasses, using hot water for make-up, restricting cooler water circulation, introducing hot saccharate cake, solution or sludge, or by heating the finished cooler solution prior to filtration, should be strictly avoided for best results.

6. Lime dispersal apparatus of a type to effect rapid and intimate contact of lime and sugar and prevent the formation of lime agglomerates is advantageous, both in reducing lime requirements and increasing filtration rates.

7. The reduction of foam in the cooler solution during lime addition, and afterwards through the filters, to the lowest possible limits is of paramount importance. Piping, tanks, stirrers and pumps between the coolers and filters should be arranged for minimum foam production.

8. Drum filters must be maintained in good condition. Filter leaks are extremely detrimental.

9. Oscillating spray bars, efficient non-clog spray nozzles, properly spaced, together with individual strainers on each filter, are essential to optimum washing of cold cake.

10. Wash water should also be the coldest water available, and only that amount necessary to displace the waste water in the cake should be used.

[1] Great Western Sugar Company.

To combine all of these important features for optimum results is not easy, and since the Steffen process occupies the unfortunate position of being more or less of a stepchild to the main house activities of cutting beets and crystallizing sugar, it is possible that this operation does not normally receive the detailed attention which it deserves. Any excessive loss of sugar in Steffen waste and/or the use of excess lime can run into serious financial losses, which, obviously, are to be avoided if at all possible.

From a review of the Great Western Steffen process results for a number of years prior to 1951, it was quite apparent that full benefit of the known principles was not being realized. A full scale demonstration of the possibilities seemed to be indicated.

Based on the premise that "one look is worth a thousand words," pilot plant equipment was set up and operated to demonstrate the results obtainable under controlled conditions of time, temperature, solution concentration and lime addition. The results followed the book. Repeated tests were run with coolers held throughout the cycle at 10° C., with six to seven percent sugar in the cooler solution, and lime additions not in excess of 100 percent on sugar. Under these conditions cooler waste was uniformly under 0.50 percent sugar and the total calculated loss was well under 2.00 percent on sugar introduced. The finished cooler solution was filtered over a pilot plant size drum filter, without pre-heat, at the rate of 9½ to 10½ sq. ft. of filter surface per ton of molasses equivalent. The advantage of low wash water temperature was also demonstrated. Wash water at 17° temperature showed an increase of 30 to 50 percent in sugar between cooler and filter waste, while wash water at 6° C. showed only a 5 to 10 percent spread. This should be expected since the colder the water the less disintegration of saccharate precipitate takes place during the filtering operation.

The supervisory and Steffen House operating personnel of this company were brought in to see the demonstration and the whole procedure discussed in detail. During these discussions it developed that various minor changes in piping, equipment and procedure gave promise of improvement in operation. Many of these adjustments were made. Two features were given particular attention: The first was to eliminate any piping or pumping arrangement which would have a tendency to produce foam. Foam retards filtration, tends to disintegrate the saccharate, and in the cooler prevents intimate contact of lime and sugar. The second point was to design some mechanical arrangement to insure prompt and intimate mixture of the ground lime with the cooler solution. Over the years, the records show that sundry and various schemes have been tried for this purpose, these schemes including sieves, bolters, blowers, spinning discs to throw the lime over the surface of the cooler liquor, etc. None of these methods has survived the test of time. Based on some previous experimental work, another idea was developed which seemed to give some promise of benficial results. This was to install two screens (about ⅛ inch woven wire mesh) set horizontally about half way down in the well of the cooler, one stationary and the other attached to an extension of the cooler propeller shaft, the two screens located as close together as possible without interference and occupying the entire cross section of the cooler well. The lime being added in more or less a continuous stream at the center of the down-flowing current

of liquor would necessarily pass both screens and be pretty well dispersed in the solution. This was done at a number of plants for the 1951 operations.

At factories where conditions were such that equipment arrangements and methods of procedure could be set up to closely approximate the pilot plant operation, the results for this past campaign were quite gratifying.

The figures in Table 1 from the Sterling factory, R. H. Myers, superintendent, and from Gering, S. L. Force, superintendent, indicate what results may be expected from close control and strict adherence to basic principles.

Table 1.—Steffen House Operating Data, Comparative Results, 1950-'51 and 1951-'52 Campaigns.

	Sterling, Colorado, Factory					Gering, Neb., Factory	
	[1]10/8-10/18-'51 Warm Water Period	10/18-11/25-'51 Lower Temp. Cooling Water	11/25-12/17-'51 Lowest Temp. Water	1951-'52 Camp. Av'ges.	1950-'51 Camp. Av'ges.	1951-'52 Camp. Av'ges.	1950-'51 Camp. Av'ges.
Cooler Sol. % Sugar	5.26	5.98	6.12	5.92	5.20	5.94	5.69
Cooler Waste % Sugar	.46	.23	.22	.25	.25	.36	.44
Filter Waste % Sugar	.57	.35	.32	.37	.38	.43	.48
Tota! Waste % Sugar	.22	.07	.07	.09	.11	.08	.13
Cold Sacc. Wash Temp. ° C.	24	16	8	13	26	11	18
Finish Cooler Temp. ° C.	23	17	14	16	17	15	19
Lime Pw'dr % CaO	88.7	88.2	89.2	88.6	89.1	88.2	86.3
Lime Add. % Sug. In Mol. Wk'd.	120	106	100	104	126	113	133
Loss % Sug. In Mol. Wk'd.	4.22	2.01	1.25	1.88	2.01	1.83	2.58

[1] Some mechanical adjustments being made during this period.

In a letter in connection with his 1951-52 results, Mr. Myers comments as follows:

> "In summing up the operation of the Steffen House at Sterling the past campaign, we are listing the points which in our judgment were most responsible for the improvement:
>
> "1. A good quality of burned lime, not overburned nor underburned, ground to a screen test of not over 1 percent plus 200 mesh, finer if possible. Without pretty good lime, operation is not going to be good.
>
> "2. All operation to be as cold as possible with an ample supply of cooling water.
>
> "3. Dispersal screens in all coolers. The powdered lime is well dispersed throughout the solution and more surfaces of lime are exposed for lime-sugar action.

"4. Keep foam to the minimum, especially in coolers and filters. The combined effect of eliminating 'foam makers,' together with the installation of dispersal screens and use of an effective chemical foam breaker, did a good job the past campaign.

"5. Even operation and close attention to all details in producing coolers. All finished coolers as near alike as possible and a frequent check on the operation of lime scales and lime addition.

"6. Filtering equipment in clean, serviceable condition, clean cloths, clean sprays and tight vacuum heads on all the drums."

Mr. Force at Gering has this to say:

"There was considerable improvement in our operations over the previous year. Nothing new or spectacular was tried, but, in the main, the improvement can be attributed to the time-tested principles, with even, consistent operations and close attention to detail.

"The following items are considered significant:

"1. The coldest water available was used both for coolers and for washing filters.

"2. Drum filters were put up and maintained in excellent shape.

"3. All foam-making piping arrangements were eliminated as far as possible.

"4. Run the making of coolers and the cleaning of filters on a uniform time schedule. This makes for uniform results."

Of the nine Great Western Steffen Houses, these two houses, Sterling and Gering, did the best work last year. The other houses made improvements over past performances in varying degrees. With this experience as a background, it is expected that the future will continue to show beneficial results of the educational program.

Notes on Symposium on Carbonation

P. W. Alston[1]

In the Morehead, Minnesota, factory of the American Crystal Sugar Company, the lime addition system is divided so that lime is added at both the top and bottom of the carbonation tank. The lime addition at the bottom of the carbonating tank is controlled to give an alkalinity of approximately .005 below that in the secondary tank.

Operating results for the four years were presented. The 1951 results were with the divided lime addition:

Year	Lime Cake Loss	Alkalinity	Soda Ash Addition	Lime Salts	Wash Water % Coke
1948	.10	.089	.72	.084	121
1949	----	.104	.98	.066	----
1950	----	.102	.67	.046	----
1951	.04	.077	.22	.036	83

It has been reported that this method of lime addition at another factory showed little or no improvement over single addition.

The Great Western Sugar Company described a pilot plant experimental first carbonation station at Loveland. Following is Mr. Dahlberg's description of the pilot plant and remarks on factory installation:

> "The station consists of a primary and a secondary tank, each 10 inches in diameter and about 5 feet high. Above the tanks is a Howard feeder for the addition of lime and raw juice. The milk of lime enters the side of the primary tank about 28 inches above the bottom. The gas distributor in the secondary tank is a copper, perforated ring designed to give good gas distribution.
>
> "The raw juice and the recirculated juice are mixed before any milk of lime comes into contact with the mixture. The recirculation is done by means of an axial flow pump. The speed of the pump can be varied to give anywhere from 2 to 12 turnovers. The volume of flow is approximately ½ gallon of juice per minute. Both primary and secondary tanks are equipped with paddles for slow stirring.
>
> "The first experimental work planned is to make a very careful comparison of Micromax and Speedomax controls.
>
> "Notes on Factory Carbonation: Quite a number of our factories are equipped with Dorr continuous carbonation, and others are still equipped with batch carbonation. I think it can be said without much fear of contradiction that up to the present time the batch carbonation gives the best quality of juice. This is indicated both by lower lime salts and lower color values percent on nonsugars. However, continuous carbonation has so many advantages in the saving of labor and material on the filter press station that we are compelled to accept somewhat poorer quality juice in return for the reduction in costs.
>
> "During the past campaign, we made a survey of all of our first carbonation stations and found greater differences in equipment

[1] General Chemist, Spreckels Sugar Company.

than we had realized. It is hard to explain how some of these differences in design came about, but it's demonstrated that we have them from time to time. Several things were demonstrated in this survey: (1) The variability of lime addition percent on beets from hour to hour was even greater than we thought it was; (2) there is evidence in several factories of poor mixing and stratification, causing the final juice to be a mixture of under- and over-carbonated juice; (3) the control of pH by the Micromax equipment left much to be desired; (4) no one knew the number of turnovers that was actually being used at any one factory.

"As a result of this survey, it was decided to install a small continuous carbonation station at our Development Laboratory at Loveland. The first study that will be made at this station will be to compare the efficiency of Micromax and Speedomax controls. After we have established the best method of control, various other items of information will be gathered such as the most desirable number of turnovers, the best method of mixing raw juice and carbonated juice, and the effect of various changes in procedure on the settling rate. It is, of course, highly important that high settling rates be secured so that the time of retention in a Dorr thickener can be reduced."

Spreckels has had a laboratory-size complete plant where as small a quantity as 100 pounds of beets can be sliced, diffused, carbonated, the juice concentrated and the standard liquor boiled to granulated sugar. This plant has been of inestimable value, not only for experimental purposes, but at times of difficulty in settling juices the pilot plant has been able to point the way to overcoming the difficulties.

Many phases of the carbonation process have been studied and reported on at meetings of the association and in the sugar journals. Comparison can be made between the standard Dorr system and the various European systems so recently reported in the literature.

Some of the important determinations made on the plan are:

The advantage of alkalinity over pH for control.
Effect of retention time in process on lime salts and color.
Value of additional lime addition.
Effect of temperature on beets of high invert content.

Mr. Campbell of Dorr Company described the work in Europe on the Wicklund process, the Dedek preliming and the French work. Most of these have been described in recent literature.

The use of centrifugal pumps for handling the muds was generally condemned as causing lower filtration rates. The gravity handling of muds was advocated as the best means for obtaining high filtration rate.

Symposium on Effective Alkalinity

HUGH G. ROUNDS[1]

History

The term "Effective Alkalinity" was originated by H. Bruniche-Olsen of the Danish Sugar Company, who first reported on this work in the October, 1947, issue of "Sugar" in an article entitled "The Physical Chemistry of Second Carbonation." Soon after this article was published we of the Amalgamated Sugar Company began an investigation of the principles of effective alkalinity in order that we might apply them to our carbonation process. Mr. Olsen and A. Brieghel-Muller further explained this concept in the April, 1949, issue of "Sugar."

Definition

Effective alkalinity is measured on first carbonation juice and is that alkalinity which is active in binding carbon dioxide and deliming the juice. It is computed by measuring the alkalinity of the juice to 9.25 pH and subtracting from this value the lime content of the juice as measured by either the soap or versenate method.

Uses

1. The value of effective alkalinity will stand as a record of juice quality.

2. Knowing the value of effective alkalinity, one can control second carbonation properly both as to the correct corbonating point and, if necessary, the proper amount of soda ash to add. When we say proper control of second carbonation we are referring to that control which will provide the lowest possible limesalts.

Results at Nampa

In the 1948 campaign at Nampa, Idaho, where this concept was strictly adhered to, we realized a reduction in residual limesalts of 34 percent, which resulted in an increase of 46 percent in tons of beets processed for each evaporator body boil-out.

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[1] Central Laboratory Supervisor, Amalgamated Sugar Company.

RECORDS OF THE SOCIETY

Minutes of the Seventh General Meeting American Society of Sugar Beet Technologists

The business session of the Seventh General Meeting of the American Society of Sugar Beet Technologists was called to order by its president, P. A. Reeve, at 3:30 o'clock p. m., February 7, 1952, in the Lafayette Ballroom of the Hotel Utah, Salt Lake City, Utah.

The chairman thereupon called for the reading of minutes from the Sixth General Meeting held in Detroit, Michigan, February 8, 1950. Upon motion duly seconded and unanimously carried, reading of the minutes was dispensed with.

The chairman then called a reading of the Report of the Secretary. The report is herewith affixed to and becomes a part of the minutes:

Report of the Secretary

The active paid-up memberships in the Society are distributed as shown below:

	Company	Individual		Company	Individual
Alabama		0	Pennsylvania		0
Arizona		3	Rhode Island		0
Arkansas		1	South Carolina		0
California		67	South Dakota		5
Colorado		65	Tennessee		0
Connecticut		2	Texas		0
Delaware	1	0	Utah		42
Florida		0	Vermont		0
Georgia		0	Virginia		0
Idaho		27	Washington		8
Illinois		10	West Virginia		0
Indiana		0	Wisconsin		2
Iowa		2	Wyoming		5
Kansas		4	District of Columbia		3
Kentucky		0	Canada	1	21
Louisiana		2	Belgium		1
Maine		0	Denmark		4
Maryland		2	England		1
Michigan		52	Hawaii		1
Massachusetts		1	Haiti		1
Minnesota		9	Ireland		3
Mississippi		0	Mexico		1
Missouri		2	Netherlands		1
Montana		12	Sweden		1
Nebraska		6	Uruguay	1	2
Nevada		0			
New Hampshire		0	Totals	3	399
New Jersey		0			
New Mexico		1	Individual Members within the U. S.		362
New York		13			
North Carolina		0	Individual Members outside the U. S.		37
North Dakota		0			
Ohio		12	Company Memberships		3
Oklahoma		0			
Oregon		4	Total Membership		402

These figures indicate a gain in total membership since the last General Meeting of 67 individuals, or 46 greater than the membership of any previous biennium. This increase in numbers is due to the stimulation attained through active and informative programs creating a desire to participate and exchange data derived through comprehensive individual and company research programs.

The Proceedings of the 1950 meeting were published and distributed in April, 1951. As of December 31, 1951, 235 copies remain in the secretary's office after distribution to the membership and outside sales. More than 100 copies have been mailed to foreign countries. Similarly, a large number of previous Proceedings have been sold, leaving total on hand January 1, 1952, as follows:

1937 Proceedings	1
1938 Proceedings (Salt Lake City meeting)	4
1940 Proceedings, Part I (Denver meeting)	60
1940 Proceedings, Part II (Denver meeting)	60
1942 Proceedings (Salt Lake City meeting)	81
1944 Regional Proceedings (Detroit, Michigan)	2
1946 Proceedings (Denver meeting)	240
1947 Regional Proceedings (Detroit, Michigan)	2
1947 Regional Proceedings (Salt Lake City)	2
1948 Proceedings (San Francisco meeting)	283
1949 Regional Proceedings (Detroit meeting being reprinted)	1
1950 Proceedings (Detroit meeting)	235
1951 Regional Proceedings (Detroit meeting)	41

Your secretary has continued an exchange of publications with several foreign and U. S. organizations in effort to enlarge the present library. This information remains available to the membership.

Respectfully submitted,

(Signed) JAMES H. FISCHER, *Secretary.*

Upon motion made and duly seconded, the Report of the Secretary was unanimously accepted as read to the Society.

The chairman then called for a reading of the Report of the Treasurer. The report is herewith affixed to and becomes a part of the minutes:

Report of the Treasurer

Herewith is submitted the Treasurer's report covering the two-year period, January 1, 1950, through December 31, 1951:

Receipts

Membership Dues and Abstracts	$2,332.66	
Registration Fees and Banquet Tickets	1,450.21	
Book Sales	2,004.80	
Company Grants	7,312.89	
Reprint Charges	969.75	
Postage	51.73	
Page Overage (Proceedings)	682.00	
Miscellaneous (Account Credit)	29.38	
Total Receipts	$14,833.42	
Balance January 1, 1950	1,999.66	
TOTAL BALANCE AND RECEIPTS		$16,833.08

Disbursements

Meeting Expenses (Banquet, etc.)	$ 1,961.98	
General Office Expense	470.77	
Printing, Engraving, Binding and Editing of Proceedings	8,613.53	
Reprints	906.31	
Postage	402.17	
Miscellaneous (Refunds)	21.00	
Total Disbusements	$12,375.76	
Balance on Hand January 1, 1952		$ 4,457.32

Respectfully submitted,

(Signed) JAMES H. FISCHER, *Treasurer.*

Upon motion made and duly seconded, the Report of the Treasurer was unanimously accepted as read to the Society.

Report of the Nominating Committee

The chairman thereupon requested the report of the nominating committee. Such report was then presented by the chairman of the nominating committee. This report included a list of candidates for each of the elected offices of the Society. Upon motion duly made and seconded to accept the report of the nominating committee incorporating a slate of candidates for the elected offices of the Society, the report was accepted unanimously.

The chairman then invited further nominations from the floor. There being no further nominations, a motion to close nominations and proceed with the balloting was made, duly seconded and passed unanimously. The chairman thereupon advised that the ballots be distributed to the members and instructed them to mark their ballots and present them to the teller committee appointed to tally the count. This committee was then excused and asked to report at the evening banquet. The report of the teller committee is herewith affixed to the minutes:

> The result of the ballot cast this day for officers and advisory council members of the American Society of Sugar Beet Technologists for the biennium 1952-1953 and until duly succeeded by succeeding election or appointment is as follows:

President	Charles E. Cormany
Vice President	Bion Tolman
Secretary-Treasurer	James H. Fischer
Immediate Past President	P. A. Reeve
Advisory Council, West Coast	Russell T. Johnson, L. D. Leach
Advisory Council, Intermountain	Frank N. Rawlings, Myron Stout
Advisory Council, Eastern Slope	L. H. Andrews R. H. Cotton, A. R. Downie
Advisory Council, Eastern United States	M. G. Frakes H. L. Kohls
Advisory Council, Eastern Canada	B. E. Easton
Advisory Council, Western Canada	F. H. Peto
Advisory Council, At Large	Robert S. Gaddie, R. J. Tingley

Report of the Committee on Constitution and By-Laws

The chairman then requested a report of the committee on Constitution and By-Laws. In accordance with Article XII of the Constitution the committee reported that the membership had been sent notice of several proposed changes in the Constitution and By-Laws at least 14 days prior to this General Meeting. The committee proceeded with an explanation of the proposals to change Article III, Section 2, paragraphs three and four; add a paragraph to Article IV on Sections; change the Section on Dues under By-Laws; and incorporate into the By-Laws a section on Awards to include Meritorious Service Award, Forty-Year Veteran Award, In Memoriam and Citation of Awards. A motion by this Committee, that such proposed changes as presented be accepted was duly seconded and unanimously carried[1].

The Constitution and By-Laws Committee chairman proposed a change in Article VII pertaining to election of Officers and Advisory Council. A motion duly seconded, that the necessary procedure be followed to conduct a vote on this change passed unanimously. The Secretary was instructed to conduct a mail ballot on said proposal.[2]

The chairman then requested a report from the resolutions committee. The Report of the Resolutions Committee as presented was unanimously adopted by the members and is recorded herewith and becomes a part of these minutes:

Report of the Resolutions Committee

I. Be it resolved that a vote of appreciation be given all those who have made this Seventh General Meeting an outstanding success. Special recognition is due the following:

1. Our President, P. A. Reeve; Secretary-Treasurer, J. H. Fischer, and other members of the Executive Committee, and the Advisory Council, for a competent job of conducting the affairs of this Society during the current biennium, including the publication of an excellent volume of Proceedings for the 1950 meetings.

2. General Program Chairman Bion Tolman, his five sectional chairmen and several sub-sectional chairmen to whom much credit is due for a splendid program.

[1] These changes appear in the Constitution and By-Laws as printed in the appendix of this issue of the Proceedings.

[2] Mail ballot on this proposal was terminated June 30, 1952. The proposal carried and appears printed in the appendix of this Proceedings.

3. General Arrangements Committee, W. F. McCrea, G. R. Larke and L. W. DeWald, for handling the numerous details so necessary to the successful conduct of this meeting, especially since the attendance has greatly exceeded that of any previous meeting.

4. Herbert Bush, who, with able assistance, handled the registration. Mr. Bush is due special recognition for having engineered the registration for every General Session of this Society since 1940.

5. J. Reuben Clark, Jr., and L. L. Madsen, guest speakers, for their notable contributions to this program.

6. J. H. Fischer, W. F. McCrea and Glenn Larke for capable handling of publicity and display materials for this meeting.

7. The Utah-Idaho, Amalgamated and Layton Sugar Companies for capable planning and generous financial support for entertainment during the meetings.

8. The Church of the Latter Day Saints for providing Tabernacle facilities for a special organ recital.

9. The management of Hotel Utah for its fine cooperation and to its employees for pleasant and courteous attention to our needs.

II. Be it further resolved that due recognition and appreciation be extended to the Beet Sugar Development Foundation for support in excess of $7,000 for printing the 1950 Proceedings and for assurance of similar support necessary for printing the 1952 Proceedings, in addition to the efficient service of J. H. Fischer as Secretary-Treasurer of the Society.

III. Be it further resolved that the American Society of Sugar Beet Technologists recommend that funds be made available by the Federal Government for the construction, maintenance and operation of a central storage facility at Fort Collins, Colorado, for the storage of valuable germ plasm which may be used in the breeding of better adapted varieties of economic crops.[a]

It is the sad duty of the Resolutions Committee to record the death of four of its esteemed members during the current biennium:

JAMES B. BINGHAM
ERNEST BENNION
ROBERT A. BOYD
ADOLF ZENZINGER

A brief biographical sketch of each of thees men is incorporated in this report and copies of the same are to be sent to the next of kin with an expression of sincerest sympathy from this Society

Respectfully submitted by the Resolutions Committee,

H. E. BREWBAKER
C. E. CORMANY
H. P. H. JOHNSON

Following adoption of the above resolution, the chair invited the meeting to rise for a moment of silence in reverence to those members deceased.

The chairman then opened the session to invitations for the 1954 General Meeting. Invitations were presented from Sacramento, California, Omaha, Nebraska, and Denver, Colorado. A show of hands vote accepted the invitation from the Denver delegation.

The meeting was declared adjourned at 4:30 o'clock p.m.

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[a] Send copy to Secretary of Agriculture and Chief of the Budget Bureau, U. S. Government.

In Memoriam

JAMES B. BINGHAM

1889 - 1950

The American Society of Sugar Beet Technologists has lost a true supporter and friend in the passing of James B. Bingham.

Mr. Bingham was born in Boston, Massachusetts, on September 27, 1889. He started his employ with the American Crystal Sugar Company in July, 1906, as a File Clerk in the Denver Office and was, through successive promotions, brought up to Eastern District Manager, which position he had held since 1937.

Mr. Bingham has left his imprint on American sugar beet agriculture. He not only was an enthusiastic leader in the mechanization of the beet crop, but also was a soil conservationist in the strictest sense of the word. The almost universal practice of sweet clover green manure and summer fallow in the Red River Valley is a fitting memorial to his efforts in this direction.

He was a recipient of the Forty-Year Service Award by the American Society of Sugar Beet Technologists in 1950. He was very active in civic clubs and community affairs in East Grand Forks, Minnesota, and Grand Forks, North Dakota. His loss is keenly felt by our Society.

ERNEST BENNION

1884 - 1951

Ernest Bennion, a pioneering beet sugar agriculturist and a charter member of the American Society of Sugar Beet Technologists, died in Lethbridge, Alberta, May 2, 1951.

He emigrated from Taylorsville, Utah, where he was born January 10, 1884, to southern Alberta in March, 1905, farming and ranching with success, until the reverses of the hard winter of 1919—which were disastrous to all ranchers in the west.

First employed by Utah-Idaho Sugar Company in 1924, he helped lay the foundation for successful beet culture under irrigation for the Raymond Sugar Factory. Accepting increased responsibilities, he became Agricultural Superintendent for the factory at Picture Butte in 1935, and led the way in development of the Lethbridge Northern Irrigation District.

Ernest Bennion was of the old school, practical and exacting. He not only told farmers why, he showed them how. And with boundless energy, by persistent hard work, he securely set the present practices which are followed in the irrigated beet areas of Alberta. Peace to his memory.

ROBERT A. BOYD

1887 - 1951

The sudden death by heart failure, July 5, 1951, of Robert A. Boyd, General Superintendent of the British Columbia Sugar Refining Company, shocked his wide circle of friends in the sugar industry. He had served his company for almost forty years. Mr. Boyd was born in Scotland in 1887 and was educated at the Glasgow Technical School and Glasgow University. He worked with Soddy on radioactive materials and became a Fellow of the Institute of Chemistry. He came to Canada in 1911 to be a demonstrator in Chemistry at the University of Toronto.

In 1912 his connection began with the company with which he was to be associated for the next thirty-nine years. From Chemist, he became Refinery Manager and eventually General Superintendent of all the operations of the British Columbia Company; its beet sugar subsidiary, Canadian Sugar Factories Limited, and its raw Cane Sugar mill at Ozama, Dominican Republic.

He had been a member of the American Society of Sugar Beet Technologists for some years, and took a keen interest in its development. His associates will long remember his quiet, analytical, and pleasing personality.

ADOLF ZENZINGER

1893 - 1951

Adolf Zenzinger, plant superintendent of the Manitoba Sugar Company Limited, died suddenly at Winnipeg May 2, 1951. He had been a member of the American Society of Sugar Beet Technologists for some years.

Mr. Zenzinger was born in Czechoslovakia March 23, 1893. He graduated from the University of Brno, Czechoslovakia, in the class of 1919 as a Mechanical Engineer. After graduation he was employed for 20 years with the "First Brunner Machine Factory," famous for the design and manufacture of all kinds of machinery for industries and especially sugar factories. Mr. Zenzinger was instrumental in building beet sugar factories in various parts of the world and finally in 1940 in Manitoba, when he became affiliated with the Manitoba Sugar Company.

His untimely death left a void among his friends and also in the Canadian Beet Sugar Industry which will be difficult to fill.

Distinguished Service Awards

Forty Year Veterans

Certificates of Appreciation and Award were gratefully presented at the Seventh Biennial Meeting of The American Society of Sugar Beet Technologists to those who have for forty years given faithful service to the Beet Sugar Industry of America. Since first they devoted themselves to this field of activity, they have seen the industry grow from a struggling infant to a place of honor among the most useful industries of the nation. They have, through the untiring labor of their hands . . . in the ideas they contributed . . . and by the inspiration of their courage, diligence and faith in the future, played an important part in the development of the industry which has proudly paid honor to them.

R. M. DANIELS

R. M. Daniels started his work with the beet sugar industry at Eaton, Colorado, in 1912 as bench chemist. He worked through all positions in small and large laboratories for the Great Western Sugar Company, serving as Chief Chemist at Eaton, Brighton, Greeley and Longmont and, in 1919, being appointed Travelling Chemist with the supervison of the laboratories at Eaton, Greeley, Windsor and Brighton.

May 1, 1920, he joined the Holly Sugar Corporation staff as General Chemist. He was transferred to the operating department in 1923 as Superintendent of the Delta, Colorado, factory. The next year he was transferred to Santa Ana, California, to develop new improvements and place the same into operation.

December 1, 1936, Mr. Daniels was transferred to the main office in Colorado Springs as General Superintendent with the supervision of the Mountain District factories. Supervision of the agricultural department or the Mountain Factory District was added to his duties in 1943. Such agricultural duties were relinquished in 1944 when he was given the responsibility of overseeing the California operating department. His status has not changed since that time to date other than having the Research Department placed under his supervision.

During these years, he has done a great deal in research and has developed for the industry the application of the La Feuille Pan, hydrate process and the complete recovery and use of waste lime. This latter development has been of major consequence in the operation of the Alvarado, California, factory since 1940.

He has also handled labor negotiations in the mountain district since 1937, and was very active in local and Federal War Production Board matters during the second World War.

JAMES E. ELLISON

James E. Ellison, one of the best loved characters in the Beet Sugar Industry, is present tonight to receive the Forty-Year Veteran Award. Jim, as he is affectionately known, entered the Beet Sugar Industry with the building of the plant at Raymond, Canada, in 1908. Canada was a new country then, and the industry had many problems. After about seven years, the same interests which owned the plant in Canada built a plant at Layton, Utah, and Jim was transferred from the management of the Canadian operations to Layton as Manager, which position he has filled successfully ever since. Jim has served his company and the industry well. He has always been an active participant in the affairs of the United States Beet Sugar Association. He served on the Advisory Committee of the industry for the work at the University of California.

It is probable that Jim has more friends in the Beet Sugar Industry than any other man; that is a wonderful tribute. The warmth of his friendliness will ever be remembered.

BERT O. MC CULLOCH

Bert O. McCulloch was born in Logan, Utah, November 14, 1883. He was educated in the Logan Public Schools and also attended the Utah State Agricultural College. McCulloch began his employment with the Amalgamated Sugar Company in July of 1903, where he served in the first and second sugar boiling stations.

He served successively as assistant superintendent at the Logan, Ogden and Lewiston, Utah, factories, and the Twin Falls and Rupert plants in Idaho. During October, 1916, he was appointed superintendent at the Burley, Idaho, factory where he served in this capacity until 1927.

After the infestation of white fly, which temporarily closed the Idaho factories, McCulloch was transferred to the agricultural department on January 1, 1928, and since that time he has served as fieldman, labor agent and labor supervisor. During the years from 1942 to 1944, inclusive, McCulloch was under-director of the War Food Administration in the movement, placement and supervision of Japanese, German and Italian prisoner of war personnel who worked in the sugar beet fields of Idaho, and since 1915 he has pioneered in the use of Navajo Indians in sugar beet agriculture.

During the last two decades, McCulloch has devoted considerable time to experimental work in fertilizing, planting and thinning operations in various types of soil.

JOHN HENRY ROSKELLEY

John Henry Roskelley was born in Smithfield, Cache County, Utah, October 30, 1886. He went to school in Smithfield and to B. Y. College at Logan, Utah. During this time, he worked on his father's farm until August 6, 1906, at which time he left for an L.D.S. Mission to Japan, returning home May 12, 1911. On September 20 of the same year, he was married to Hanna Favell Buck and has four daughters.

In February, 1912, he started working for the Amalgamated Sugar Company as a Japanese Interpreter and Labor Agent, and has been continuously employed by the company since that date.

R. J. SMITH

R. J. Smith was first employed in the beet sugar industry by the Great Western Sugar Company in 1912 as a bench man in the laboratory at Greeley, Colorado. Miscellaneous inter-campaign work was continued and in 1913 he was made Beet Laboratory Foreman.

In 1914, he was transferred to Windsor, Colorado, as assistant chemist and returned to Greeley in 1915 where he held again the position of assistant chemist. The company transferred him to Longmont in 1916 and he remained there until 1918. Part of 1918 and 1919 were spent in military service. Upon release from service, he was appointed chief chemist at Longmont, serving in this capacity until May, 1920, when he resigned to accept a position with the Holly Sugar Corporation as chief chemist at Swink, Colorado. This position was held until 1923 when he was appointed general chemist at the main office of the Holly Sugar Corporation in Colorado Springs. This new position gave him supervisory duties over all the factory laboratories and beet laboratories in Colorado, Wyoming, Montana and California. In 1949, Mr. Smith was given the title of statistician, which he holds at the present time.

During his tenure with the beet sugar industry, he has completed experimental studies in determining sugar losses in beets in storage. Some of his results are reported in the 1940 Procedings. Also reported in a later Proceedings are the results of developmental work with a photo-electric apparatus for determination of color and turbidity in fine sugar.

He is also credited with considerable work on the hydrate process to reduce lime addition in molasses in the Steffen House and has worked diligently to standardize and improve beet laboratory methods and procedures. All this has required concentrated efforts on his part.

ARTHUR AYLESWORTH WRIGHT

Arthur Aylesworth Wright, born at Dresden, Ontario, in 1876, and educated at Dresden and Chatham, Ontario, is one of the original employees of the Canada & Dominion Sugar Company (formerly the Dominion Sugar Company).

Organized in 1901, with Dr. D. A. Gordon as co-founder and President, the Dominion Sugar Company commenced operations in the fall of 1902, and it was at this time that Mr. Wright joined the Company as personal stenographer to the President.

Since that time, Mr. Wright has filled several positions with the Company contingent with its expansion from a plant capable of slicing 500 tons daily to its present daily capacity of 2,500 tons. In 1906, Mr. Wright was appointed as purchasing agent, and in 1909, in addition to his many responsibilities in the purchasing and sales departments, he took on some of the duties of the Agricultural Department. In 1916, he was appointed Branch Manager, the position he has very capably continued to fill. As Branch Manager, his many duties include supervision of the Agricultural staff at the Wallaceburg plant.

Mr. Wright, while still very active in his 76th year, nevertheless plans on retirement in the spring of 1952, after half a century of continuous and meritorious employment with the company.

Meritorious Service Awards

Certificates of Appreciation and Award were gratefully presented at the Seventh Biennial Meeting of The American Society of Sugar Beet Technologists to those who have, for many years, given faithful service to the Beet Sugar Industry of America. Since first they devoted themselves to this field of activity, they have seen the industry grow from a struggling infant to a place of honor among the most useful industries of the nation. They have, through the untiring labor of their hands . . . in the ideas they contributed . . . and by the inspiration of their courage, diligence, and faith in the future, played an important part in the development of the industry which has proudly paid honor to them.

ELMER W. BRANDES

Dr. Elmer W. Brandes was born in Washington, D. C., July 15, 1891. He was educated at Michigan State College, Cornell University and the University of Michigan. Before World War I, he spent two years as a plant pathologist at the Puerto Rico Agricultural Experiment Station.

He came to the Bureau of Plant Industry, Soils, and Agricultural Engineering as Pathologist in 1919, directly from service as a Second Lieutenant in World War I. Dr. Brandes was placed in charge of research of sugar plant diseases. He devoted considerable time to the epidemic disease "Yellow Stripe" in cane which was depressed by crossing domestic varieties with wild relatives of sugar cane resistant to the disease.

Dr. Brandes also directed breeding work on sugar beets which resulted in new varieties resistant to the Curly Top disease which threatened ruin to western sugar beet growers in the late '20's and early '30's. Dr. Brandes expressed pride in the achievements of his colleagues under his direction.

At the United States Department of Agriculture Honors Day ceremony in 1949, Dr. Brandes was given a distinguished service award "for outstanding performance in leadership to agriculture through the development and administration of research programs for sugar cane, sugar beets and rubber and for fundamental research on the cause and control of sugar cane mosaic." He has received a number of other honors too numerous to mention here.

Dr. Brandes retired as head of the Division of Sugar Plant Investigations on July 31, 1951, after 32 years of federal service.

WILFORD Y. CANNON

Wilford Y. Cannon was born at Salt Lake City, Utah, July 4, 1888. He graduated with a Mechanical Engineering degree from the University of Utah in 1909. He did post-graduate work at the Royal Technical College of Saxony at Dresden, Germany.

Entering the employ of Utah-Idaho Sugar Company in 1916 as a draftsman and engineer, he served successively as Chief Engineer, Montana District Manager, Idaho District Manager, Assistant General Superintendent, General Superintendent and, at present, and for several years past, as Production Manager.

He has served the industry for several years as a member of the United States Beet Sugar Advisory Committee, working with the University of California on mechanization problems; served several years as chairman of the Curly Top Resistance Breeding Committee; has served one term as president of The Beet Sugar Development Foundation and is a Past President of The American Society of Sugar Beet Technologists.

DAN GUTLEBEN

Dan Gutleben's first contact with the beet sugar industry was as a young engineer on the construction job of a beet sugar processing plant near Ames, Nebraska, in 1899.

After the hectic beet sugar plant construction period of the first decade of this century calmed into a lull, Dan turned his attention to beet sugar plant operations and continued as a beet sugar operating engineer until 1921.

As Chief Engineer for the Pennsylvania Sugar Refinery in Philadelphia, he built a lasting monument to himself which undoubtedly still will show many of his hammer marks. Dan retired from the Pennsylvania in 1945. But long before this date, Dan, among all of his other activities, turned his attention to historical sugar lore and data, especially of the men of the Beet Sugar Industry. His annual "Sugar Tramp" is eagerly awaited among sugar men from Western Europe and England to the Philippine Islands, and all the sugar-producing areas in between.

Even when still fully occupied as Chief Engineer of the Pennsylvania Refinery, he gave much time and thought to historical sugar lore. His real activity in his search for historical lore began with his retirement from the Pennsylvania Refinery. Since 1945, he has travelled more than 75,000 miles, principally via automobile, except for his water hops to Britain and Hawaii. He has read hundreds of sugar journals, many volumes of newspapers going back almost a century and has abstracted and photostated tens of thousands of words, all carrying some sugar lore. Dan says he will need ten years more to complete his task. We hope the time is granted him.

In this search for sugar data, he has had the constant and helpful assistance of Mrs. Dan Gutleben. She has undoubtedly read more sugar journals and other sugar information than any other woman, and, in paying tribute to Dan, have in mind that Mrs. Dan is deserving of a large share thereof.

J. G. LILL

J. G. Lill was born on a farm in Sedgwick County, Kansas, May 16, 1889. He attended the public schools of Kansas and graduated with the degree of Bachelor of Science from Kansas State College in 1909. After another two years of study he received the degree of Master of Science in Agriculture in 1911.

During the years 1911 through 1913, he worked for the Kansas State Agricultural Experiment Station, and entered the employ of the United States Department of Agriculture in April, 1913, as an Assistant in the Division of Dry Land Agriculture. From there he was transferred to the

Division of Sugar Plant Investigations in 1915 and was stationed at Rocky Ford, Colorado.

He was called out with the Colorado National Guard in 1916 and spent three years in the army. After the completion of military service, he returned to duty with the Division of Sugar Beet Investigations in 1919 and was transferred from Rocky Ford, Colorado, to East Lansing, Michigan, in 1924. He has remained there since that time.

He has been responsible for agronomic research for humid areas and is looked upon by the Michigan Beet Sugar Industry as a Dean of Sugar Beet Culture. His results of agronomic testing of sugar beets have appeared in several publications and bulletins.

WILFRED WILLIAM ROBBINS

Dr. Robbins received an A.B. degree from the University of Colorado in 1907 and an M.A. degree in 1909. In 1917, he received a Ph.D. from the University of Chicago.

He is a member of The American Society for the Advancement of Science, Botanical Society of America, American Society of Naturalists, Sigma Xi and Alpha Zeta.

During the years 1908 to 1911, Dr. Robbins was an instructor in Biology at the University of Colorado and an instructor in Botany and Forestry at Colorado Agricultural College from 1911 to 1913. He became an Assistant Professor in 1913 and, in 1914, a Professor of Botany and Botanist at the Experiment Station, which position he held until 1919. At that time, he entered the employ of the Great Western Sugar Company as Plant Physiologist and Pathologist. Dr. Robbins remained with the Great Western Sugar Company until 1921 when he took a position with the United States Department of Agriculture, Bureau of Plant Industry, as Botanist in the Office of Cereal Investigations. He then went to the University of California as Associate Professor, became Professor of Botany and was Botanist in the California Experiment Station from 1922 to 1951, and has been Professor Emeritus, 1951 to date.

Dr. Robbins was District Governor of Rotary during 1944 and President of the Western Weed Control Conference, 1950-1952. He was elected President of the American Society of Sugar Beet Technologists for the biennial period 1949-50.

During 1948, he was the recipient of an Honorary Degree from the University of Montevideo.

He is the author of nine textbooks and numerous bulletins and circulars on weed control.

ANTON WILLIAM SKUDERNA

Paying tribute to its first president becomes a happy occasion for this Society. With this honor comes even greater recognition—that of showing appreciation to a person who was one of the first to envision the tremendous potential of an organization like The American Society of Sugar Beet Technologists.

Early records of this Society and the Round Table gatherings prior to the Society's formation show that Anton William Skuderna was program chairman, chairman of arrangements, a member of the committee to draft the first Society constitution and by-laws, as well as being active on the program itself. Al has given dynamic leadership and research background to many of the agronomic and seed-breeding technological developments in our industry, both before and since the formation of our Society. The past proceedings give full account of much of his work.

Born in New York City, his later homes took him gradually westward, to Wisconsin, Illinois, Nebraska, then on into Colorado. His formal agricultural study began at the Nebraska School of Agriculture in Lincoln, he later was graduated from the University of Nebraska with numerous academic honors. Some post-graduate study at Minnesota came next, then on to the employ of The American Beet Sugar Company as bench chemist in 1916, which duty was soon changed to the agricultural field. His employ with this company was interrupted by World War I where he again displayed keen leadership and was soon commissioned an officer. He rejoined the sugar company and in 1924 was appointed Agricultural Research Superintendent. During this time, the overwintering procedure of producing beet seed by the annual method was developed, as was also the care of the Flat Foliage and Leafspot-Resistant varieties.

In 1929, he was loaned to the Office of Sugar Plant Investigations, United States Department of Agriculture, to head agronomic work of that Division as Principal Agronomist with field stations in ten of the important beet-growing states. In 1935, he returned to American Crystal Sugar Company as General Manager of The American Beet Seed Company and was stationed at Rocky Ford where the research laboratories of the company are located. In 1942, he was made General Agriculturist of the company with headquarters in Denver. In 1949, he was promoted to the position of Vice President and General Agriculturist which position he now holds.

Al has always held as basic to research work the need of developing resourcefulnes, confidence and utmost honesty, both in dealings with fellow associates and subordinates.

HARRY BRUCE WALKER

Harry Bruce Walker, born and reared on a farm in McDonough County, Illinois, received his college training in Engineering at Iowa State College. He holds two degrees in Civil Engineering from this institution. For more than forty years, Dr. Walker has been engaged in engineering work as applied to Agriculture. Most of this time has been spent with colleges and universities.

From 1910 to 1928, he was a member of the faculty at Kansas State College and from 1922 to 1928 was Head of its Department of Agricultural Engineering. He was on leave from Kansas State College from 1917 to 1919 to serve in World War I as Captain of Engineers. Later, in 1927, he again obtained leave to work as Director of Research of Mechanical Farm Equipment for the United States Department of Agriculture.

Soon after the completion of this assignment, Dr. Walker resigned his position at Kansas State College to become Professor of Agricultural Engineering and Agricultural Engineer in the Experiment Station at the University of California; a position he now holds on an Emeritus basis, since his retirement from active university duties in July, 1951. For 19 years he served as Chairman of the Division of Agricultural Engineering at California and directed its research work.

Dr. Walker is a member and former Vice President of The American Society of Sugar Beet Technologists; a Fellow and Past President of the American Society of Agricultural Engineers; a life member of the American Society of Civil Engineers; a member of the American Society for Engineering Education and many other technical and scientific organizations.

In 1939, the American Society of Agricultural Engineers awarded him its John Deere Gold Medal for "Distinguished Achievement in the Application of Science and Art to the Soil."

In 1931, he became interested in the mechanization of sugar beet production and, in cooperation with the United States Department of Agriculture, at the California Agricultural Experiment Station inaugurated a research project in this field. Some six years later these researchers had progressed far enough to attract the interest of the United States Beet Sugar Association. As a result of this interest, the Association made substantial grants to the University of California for the support of this research on a more comprehensive basis. The organization and direction of this enlarged program became Dr. Walker's responsibility. It was some five years later, however, before these investigations became of sufficient general value to assure the mechanization of sugar beet production.

In 1948, he presented a paper at the San Francisco meeting of this Society entitled: "A RESUME OF SIXTEEN YEARS OF RESEARCH IN SUGAR BEET MECHANIZATION." This paper, which was so well received by our Society, was also named the same year a prize technical contribution to engineering literature by the American Society of Agricultural Engineers.

Thus Dr. Walker for sixteen years directed and conducted research and investigations of great economic importance to the Industry our Society serves.

CONSTITUTION
AND BY-LAWS
OF THE
SOCIETY

Constitution and By-Laws of the American Society of Sugar Beet Technologists

ARTICLE I

Name.

The name of this organization shall be the AMERICAN SOCIETY OF SUGAR BEET TECHNOLOGISTS.

ARTICLE II

Objectives.

The object of this Society shall be to foster all phases of sugar beet and beet sugar research, and to act as a clearing house for the exchange of ideas resulting from such work.

ARTICLE III

Membership.

Section 1. All persons, associations, corporations and other organizations interested in the advancement of knowledge concerning sugar beet production or beet sugar processing are eligible to membership in this Society.

Section 2. There shall be three classes of membership: (1) Individual membership, (2) Company membership and (3) Honorary membership.

Individual members shall have the right to attend any meetings of the Society, to vote in elections and to secure one copy of such publications as are issued by the Society.

Company members shall be entitled to have one official representative attend any General Meeting of the Society, to cast one vote at elections, and to secure one copy of the Proceedings or other report of General Meetings of the Society.

A non-member of the Society who has rendered outstanding service to the Sugar Beet Industry may be granted Honorary Membership by a unanimos vote of the Executive Committee and Advisory Council.

Section 3. Any member may be deprived of membership for non-payment of dues or for other reasons by vote of the Executive Committee of this Society.

ARTICLE IV.

Sections.

In order to provide opportunity for the consideration of specialized subjects in branches of beet sugar and sugar beet research, sections of the organization shall be divided as follows:

A. Agronomy
B. Genetics and Variety Improvement
C. Entomology and Plant Pathology
D. Agricultural Engineering
E. Chemistry and Factory Operation

Additional sections may be organized on a tentative basis for the purpose of facilitating presentation of papers with the approval of the Executive Committee. Upon evidence of ability to develop and execute a well-organized sectional program for two consecutive general sessions of the Society, sections so organized may acquire permanent status upon approval by the Executive Committee and Advisory Council. A section may be terminated by (1) a two-thirds vote of the Society members in a mail ballot following 60 days' notice by the Executive Committee, or (2) if the section fails to present a program at each General Meeting, by a two-thirds vote of the Executive Committee and Advisory Council.

ARTICLE V.

Officers.

The officers of the Society shall consist of: **President, Vice President, Immediate Past President and Secretary-Treasurer.**

These officers shall constitute the **Executive Committee.**

ARTICLE VI.

Advisory Council.

The Advisory Council shall consist of the following number of representatives:

West Coast Area	2
Intermountain Area	2
Eastern Slope Area	3
Eastern U. S. Area	2
Eastern Canadian Area	1
Western Canadian Area	1
At Large	2

ARTICLE VII.

Election of Officers and Advisory Council.

The President shall appoint a nominating committee of five (5) members one year in advance of the General Meeting.

This Committee shall nominate two candidates for President, two candidates for Vice President, one candidate for Secretary-Treasurer and candidates for the Advisory Council, with a minimum of one more for each section than the number to be elected.

Ballots containing the nominations shall be submitted by mail to all members of the Society one month in advance of the General Meeting. Ballots may be returned by mail or deposited in the ballot box at the General Session up to 24 hours prior to the Business Session. Write-in nominations on ballots will be honored.

ARTICLE VIII.

Duties of the Officers.

Section 1. President. The President shall be the Executive Officer of the Society. He shall instruct the Secretary to call such meetings of the Executive Committee and the Advisory Council as he deems necessary. He shall preside over the General Meeting of the Society and meetings of the Executive Committee and Advisory Council. He shall, with the advice of other members of the Executive Committee, appoint the General Program Chairman, and such committees as may be necessary, and arrange for the special guest speakers who will participate at the General Meeting.

Section 2. Vice President. The Vice President shall serve in the absence of the President.

Section 3. Secretary-Treasurer. The Secretary-Treasurer shall keep the records of the Society. He shall attend to the collection of dues, keeping of accounts and payment of bills and obligations.

Section 4. Executive Committee. The Executive Committee shall act upon all matters within the jurisdiction of the Society which arise between the meetings of the Society and, in consultation with the Advisory Council, shall formulate the policies of the Society as a whole.

ARTICLE IX.

Program Chairman.

The General Program Chairman shall, with the advice of the Executive Committee, appoint the chairman of each of the sections listed in Article IV, above. He shall be responsible for the preparation of the program for the General Meeting of the Society, instructing and advising section chairmen regarding their particular programs, advising the local arrangements committee regarding facilities and equipment necessary for the general meeting.

Each section chairman shall develop and submit to the General Program Chairman a tentative program for his section, and shall be responsible for conducting the sectional meeting at the general meetings of the Society.

ARTICLE X.

Time and Place of Meetings.

The General Meetings of the Society shall be held biennially. The place of the meeting shall be determined at the previous General Meeting of the Society and due notice shall be given to members.

Regional meetings may be held under the auspices of the Society upon approval of the Executive Committee.

ARTICLE XI.

Regional Organizations.

For the purpose of regional organizations three regions are recognized by the Society:

(1) Eastern Region
(2) Central Region
(3) Western Region

Boundaries of these regions are to be determined by the Executive Committee. When requested by representatives in any of the three regions the Executive Committee may approve formation of a regional group of the Society and the holding of meetings by such regional group. The officers of each region shall consist of Chairman, Vice-Chairman and secretary-Treasurer. If an organization does not exist in any of the three regions, the President of the Society shall, if the Executive Committee approves of the regional meetings, appoint a Temporary Chairman, Vice-Chairman and Secretary-Treasurer, such officers to hold office until a regional meeting is held and regional officers are duly elected. These officers shall constitute the Executive Committee for their respective regions and shall be responsible for the appointment of necessary committees for carrying out the various projects proposed in their respective regions. All expenditures of funds by a regional organization shall be the responsibility of that organization.

ARTICLE XII.

Amendments.

Amendments may be proposed (1) by the Executive Committee directly, or (2) by Petition of any ten members of the Society. Notice of the proposed amendments shall be submitted to the members at least 14 days before the ballot is taken. The amendment may be adopted by two-thirds of the members present at any General Meeting.

If, in the opinion of the Executive Committee, the proposed amendment should be acted upon before the next General Meeting, it may be submitted to the members by mail. If it is approved by two-thirds of those returning their ballots within thirty days, it shall be adopted.

By-Laws

1. Dues. Biennial dues for individual members shall be $5.00, and for company members $25.00 payable on or before the date of the General Meeting.

2. Registration Fees. A registration fee shall be charged those attending any General Meeting of the Society, both members and non-members. The amount of this fee shall be determined by the local arrangements committee in charge of arrangements for the meeting and be subject to approval of the Executive Committee.

3. Quorum. A quorum for the General Meeting shall consist of 10 percent of the membership.

4. Committees. The President shall appoint such standing and special committees as seems desirable for carrying on the work of the Society. He shall appoint a local arrangements committee, which shall be responsible for arranging for rooms for meetings, hotel accommodations for members and guests, the necessary equipment for conducting the meetings and entertainment for the biennial banquet of the Society.

5. Publications. All papers presented at the General Meeting, or suitable abstracts thereof, shall be presented by the section chairmen, with their appraisal of the technical and historical value of the paper submitted, to the chairman of the Editorial Board. The Editorial Board shall consist of three members appointed by the President. The Editorial Board shall be final authority in all matters covering the publication and release of Society papers, the editing of these papers and the printing of the proceedings. The Board shall have jurisdiction over the release of papers and abstracts for use other than in the Proceedings and papers submitted to the Board shall become the property of the Society. No commitment for expenditure of the funds of the Society for publications can be made without the approval of the Executive Committee.

6. Awards.

Meritorious Service Award. This award for meritorious service to the Beet Sugar Industry of North America shall be presented by the Society to members who have been outstanding in promoting the objectives of the Society and have been active in the affairs of the Society. Such awards each biennium shall not exceed two (2) percent of the current membership. A Meritorious Service Award Committee shall be appointed by the President to consider the qualifications of such persons. The committee will present such names to the Executive Committee and Advisory Council for their unanimous approval two months prior to the next biennial General Meeting. Such awards may be presented to those who have already been recipients of other Society commendations.

A "Certificate of Appreciation and Award" will be prepared for and presented to the awardee at a time and place deemed by the Society most opportune for maximum recognition.

Forty Year Veteran Award. This award shall be presented to Society members who have, since the previous biennial meeting, or who will have within one year of the current meeting, completed 40 years of active service to the Beet Sugar Industry of North America. The awardee must receive approval by the Executive Committee and Advisory Council by unanimous vote, following thorough scrutiny of his biography.

A "Certificate of Appreciation and Award" will be duly prepared for and presented to such eligible individuals at a time and place deemed by the Society most opportune for maximum recognition.

In Memoriam. A tribute to Society members deceased will be conducted by presentation of a scroll, on which a short biography is printed, to the nearest of kin. This presentation will not be made at a Society meeting, but by a Society member of close association at a time shortly following the current biennial meeting.

Citation of Awards. In addition to the presentation of certificates for the Meritorious Service and Forty-Year Veteran Awards, and scroll for memoriam citations, an appropriate citation and/or biographical sketch shall be published in the Proceedings for each such presentation.

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